NCBDS 40

TOOL(ING)

National Conference on the Beginning Design Student
North Carolina State University | College of Design
40th Annual Conference

2025 CONFERENCE PROCEEDINGS

February 27 - March 2, 2025

Proceeding Editors:
Tania Allen, Patricia Morgado, Sara Queen

NC STATE College of Design

Designing the Future of Retail: Cross-Disciplinary Collaboration in Industrial Design and Architecture Design

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ABSTRACT

The significance of design's cross-disciplinary nature has increased alongside technological advancements, as emerging technologies present both new opportunities and challenges for complex socio-technical systems. Systems thinking has drawn attention in the design field as a holistic approach to tackling complex systems by examining the interrelationships between elements. This also necessitates cross-disciplinary collaboration to address the multifaceted nature of the problems comprehensively. These aspects of systems thinking further emphasize its importance in design education to help navigate the current era of technological innovation. The future of retail exemplifies this interconnected complexity in the context of emerging technologies, because introducing them - such as robotics, artificial intelligence, and mixed reality - into retail environments requires a holistic consideration of the entire system, encompassing physical spaces, service processes, and human interactions.

This study examines a 15-week collaborative studio project between industrial design and architecture. By leveraging a systems thinking approach, the project facilitated cross-disciplinary collaboration to develop future retail concepts, enabling students to integrate their expertise and address the interconnectedness of artifacts, environments, and human interactions. Both disciplines followed a structured design process encompassing research, system design, space and robot design, visualization, and validation, while collaboration was organized around four key steps: planning, learning, prototyping, and communication. The project also involved collaboration with a supermarket chain, providing opportunities for onsite observations, employee interviews, and discussions with industry professionals. Students developed futuristic concepts for retail operations and customer experiences by leveraging the integration of mobile service robots, adaptive spaces, and mixed reality. Industrial design students focused on designing a product-service system of supermarket robots based on their redefinition of customer shopping experience and employee workflow, proposing an automated grocery order fulfillment system. Architecture students designed adaptive retail spaces that seamlessly blur the boundaries between physical and digital worlds, exploring how the Metaverse and mixed-reality interfaces can augment retail spaces and shopping experiences through dynamic, immersive interactions with digital avatars and robots. This cross-disciplinary collaboration resulted in holistic and integrative solutions for complex systems, presented through immersive VR experiences or animated scenarios.

This study's contribution to design education is threefold. First, it proposes a systems thinking approach with cross-disciplinary collaboration for designing future retail experiences, demonstrating its effectiveness in addressing and designing complex socio-technical systems. Second, it offers insights into how industrial design and architecture can be integrated to create novel user experiences in the realm of digital transformation. Lastly, by examining the design and collaboration processes and reflecting on the opportunities and challenges, this study offers insights for its application to future studio courses. Given the increased complexity and dynamics between disciplines, thorough pre-planning and flexibility are critical for the success.

Keywords:

Cross-disciplinary collaboration, Design education, Industrial design, Architecture, Future of retail

Introduction

Design is inherently integrative,[1] and its fields have become increasingly cross-disciplinary.[2] Buchanan asserts that the four broad areas of design - communication, products, services, and environments, corresponding to the field of communication design, industrial design, service design, and architecture – are interconnected and can lead to innovation by repositioning one area in the context of the others.[3] Technological advancements have further blurred the boundaries between these design areas, requiring systems approaches to solve complex problems. For example, services have been integrated as a core part of physical products with the widespread adoption of connected, smart devices relying on communication facilitated through these physical devices. Similarly, retail stores and experiential spaces have increasingly utilized smart devices, sensors, kiosks, and diverse communication media to enhance customer experiences. All of this underscores the importance of cross-disciplinary learning in design education, equipping students with the knowledge and perspectives of other disciplines and the ability to collaborate across disciplines.[4]

A particular area of interest that represents this interconnected complexity in the context of emerging technologies is the future of retail. This domain spans multiple design disciplines, and offers design students opportunities to explore and design on emerging technologies, such as robotics, artificial intelligence (AI), and the Metaverse, to create novel experiences while addressing complex challenges in the retail space. Indeed, the retail industry has already been exploring, testing, and implementing these technologies, from augmented reality shopping and smart shopping carts to robots for cleaning, inventory scanning, and customer assistance.[5] However, introducing robots into retail environments requires a holistic consideration of the entire system, encompassing the physical space, artifacts, service processes, and human interactions, that can be best addressed through cross-disciplinary collaboration. More specifically, robots exhibit autonomous and dynamic behaviors[6] as they navigate spaces, perform tasks, and interact with people. Such behaviors necessitate modifications to existing environments or the creation of entirely new ones to accommodate robots, prompting a need for novel approaches to designing the future of retail.

At the same time, a novel shopping experience using the Metaverse requires designing not only artifacts and retail environments in the digital space but also digital interfaces, service flows, and spatial interactions, ensuring seamless integration of both physical and virtual environments. The concept of the Metaverse has evolved from simple virtual worlds to sophisticated, interconnected digital environments that support immersive and interactive experiences. As defined by Mystakidis, the Metaverse is a "multiuser virtual environment blending physical and digital realities."[7] The Metaverse is built on complex architecture and infrastructure, and highlights its potential for unique social interactions and virtual legal systems.[8] By merging physical and virtual worlds through immersive technologies like virtual reality (VR), augmented reality (AR), and mixed reality (MR), the metaverse has the potential to revolutionize social, technological, and behavioral domains while addressing challenges such as accessibility, security, and user immersion.[9] This growth has opened new opportunities for consumer engagement and digital commerce.

This paper examines a collaborative studio project conducted at the University of Cincinnati's College of Design, Architecture, Art, and Planning (DAAP) in the fall of 2022. Over 15 weeks, undergraduate industrial design students and graduate architecture students collaborated to develop future retail concepts. The project followed a flexible cross-disciplinary collaboration format, where students worked in discipline-specific groups but developed concepts concurrently. Together, they designed comprehensive systems for a new retail experience, encompassing mobile service robots, user interfaces, supporting artifacts, and built environments. Industrial design students focused on a robot's product-service system, while architecture students designed adaptive spaces facilitating interactive experiences with robots, exploring how mixed reality can augment retail environments with dynamic interactions between robots and digital avatars. These designs envisioned retail environments where the boundaries between the physical and digital worlds were seamlessly blurred. The project also involved collaboration with a supermarket chain, enabling students to conduct onsite observations, interview employees, and receive regular feedback from the supermarket team. The authors, each representing the respective discipline, led the studio with holistic perspectives to address the challenges of designing future retail experiences while facilitating collaboration across disciplines and with the retail industry.

Using this studio project as a case study, this paper examines the design approaches and collaboration process, reflects on their implications, and provides recommendations for design education. The following sections discuss systems thinking and cross-disciplinary collaboration as foundational approaches of this project before delving into the studio project's process, tools, and outcomes. Finally, we reflect on student learning outcomes and the pedagogical opportunities and challenges of fostering cross-disciplinary collaboration in design education.

Approaches

Systems Thinking

Systems thinking is a holistic approach to understanding complex situations by looking at the relationships between parts and the emergent properties of a whole, rather than viewing individual parts as isolated elements. It reveals "the complexity, interrelationships, and many of the interdependencies that exist in our surroundings".[10] Compared to the past, when a designer's work was mostly on discrete artifacts or tangible solutions in isolation,[11] designers are now facing complex socio-technical systems,[12] where people and technology are intertwined, requiring simultaneous consideration of human and technological aspects. Accordingly, in the current era of rapid technological advancements and wicked problems, designers are required to deal with complex systems through a rigorous approach and collaborative efforts in cross-disciplinary teams,[13] making systems thinking more relevant than ever. One key aspect of systems thinking is multidisciplinarity. Researchers have emphasized the importance of a multidisciplinary approach to problem-solving in systems thinking,[14 15 16] calling for cross-disciplinary collaboration to address complex problems effectively. Indeed, cross-disciplinary teams are essential for comprehensively understanding and addressing the multifaceted nature of the problems from different perspectives. These aspects of systems thinking further extend to design education. Dubberly and Pangaro[17] emphasize the importance of incorporating a systems approach in design education to navigate the current time of technological innovation. Computing, data, and algorithms have not only formed this innovation but have also become critical materials for designers.

Designing for the future of retail entails a problem space comprising a complex socio-technical system of artifacts, services, experiences, and environments. We find systems thinking to be a highly appropriate approach for the future of retail project and helpful for students learning to address a complex problem space with multiple interrelated elements. Subsequently, we formed a cross-disciplinary collaboration between industrial design and architecture and applied the systems thinking approach to the project. The specific methods and processes of this collaboration are discussed in the following section.

Cross-Disciplinary Collaboration

Both industrial design and architecture studios had been taught independently over the years, at different class times, and with a different number of enrolled students, which brought up challenges for close collaboration between the two courses. Logistically, it was not feasible to bring students from both courses together in one place at the same class time. Instead, students worked within their own disciplines, developing concepts concurrently by following a mutually established project schedule. This challenge necessitated careful planning and strategies to make the collaboration successful, ensuring students learn and understand the other discipline's perspectives and approaches as they bring their expertise to the collaboration.

The collaboration process in this project can be summarized in four key steps: planning, learning, prototyping, and communication (Fig 1).

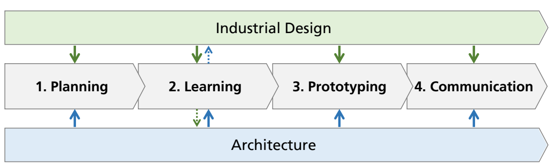

Fig 1. Four steps of cross-disciplinary collaboration.

Planning: Before the project kick-off, the two courses were aligned on the project brief, scope, and schedule. Considering the aforementioned challenges, this planning step was critical to ensure smooth and effective collaboration. At this stage, the authors also contacted a supermarket chain as an industry partner, discussing levels of commitment, arranging meetings, and securing access to its stores and staff for initial research.

Learning: To help students in both disciplines learn the perspectives and approaches of the other discipline, each author delivered a lecture to the students of the other discipline. The first author, an industrial design professor, spoke to architecture students about the design process of robots and their interactions and relationships with built environments for the accommodation of robots. The second author, an architecture professor, addressed the topic of extended reality to industrial design students, introducing VR software tools and their applications for immersive experiences in the Metaverse. Another key learning component was collaborative research on the retail environment. Students' engagement with primary and secondary research on the current situation, including store visits, interviews, and technology research, aligned the students in both disciplines with a shared foundation for the project. This research component is further discussed in later sections.

Prototyping: VR prototyping was planned for the later stage of the project. Prototyping is an effective method for bringing stakeholders together, allowing them to experience and evaluate early design concepts in a tangible way, and further developing designs accordingly.[18] Since prototypes can be experienced regardless of a participant's expertise in a specific design field, they facilitate cross-disciplinary collaboration in terms of sharing the progress of designs between disciplines and integrating design solutions. With VR prototyping, we aimed to combine the outcomes from both disciplines into a virtual environment to test how the proposed robots would operate in new retail environments and refine designs accordingly while minimizing the time and cost involved with building physical prototypes. Constructing a mock retail space and robots physically is not only cost-prohibitive for studio courses but also unsuitable for simulating the dynamic behavior of and interactions with robots. However, due to time constraints in the later stage of the project, this task was not completed. The implications of this shortcoming are further elaborated in following sections.

Communication: The final component of the collaboration was communication. A joint exhibition was held, inviting experts in relevant technologies as well as the supermarket team. This event fostered dynamic discussions and reinforced interdisciplinary collaboration by allowing students to share their work across both disciplines, present to professionals, and receive feedback grounded in real-world perspectives.

Studio Application

Project background

Under the theme of the future of retail, industrial design students were tasked with designing supermarket robots and the surrounding product-service systems, while architecture students were assigned to design adaptive spaces that facilitate interactive experiences with robots. The following project descriptions were provided to the students.

Industrial design: Students will design a wheeled mobile service robot and its design elements, including experience, aesthetics, functionality, interface, from a larger system perspective encompassing product, service, and infrastructure. This robot should aid customers and/or employees in a supermarket with specific tasks and involve direct interaction with the person(s) using it. All individuals interacting with or affected by this robot should be considered, including end-users (customers or employees), non-users (e.g., passers-by), and stakeholders. The final design outcome must:

- be about an integrated system of a mobile robot, interfaces, and service
- be based on sound technological configurations
- contain interaction elements integrated into the physical artifact, whether visual, auditory, tactile, gestural, or multi-modal.
- include UI design and a service scenario.
- be communicated through storytelling.
- be collaborative work with your team members.

Architecture: Students are challenged to explore one of two hybrid realms for their conceptual designs:

- Physical store enhanced with digital technologies and autonomous robots, exploring the seamless integration of robotics, artificial intelligence, XR, and innovative technologies within the physical retail environment to create more efficient, engaging, and adaptable spaces.
- Virtual store integrated with physical store pickup solutions, focusing on designing Metaverse that extends beyond the conventional online shopping experience, emphasizing innovative spatial experience while maintaining a connection to physical locations for product fulfillment.

Regardless of the chosen direction, students are required to maintain a strong emphasis on the spatial experience in their final designs. The goal is to investigate how three-dimensional spaces can enhance the retail experience in ways that go beyond the limitations of conventional 2D interfaces, such as websites or mobile apps. The architecture visualization class, conducted alongside the industrial design class, follows a structured *research - system design - space design - visualization - validation* process to explore and conceptualize the future retail store, augmented by the Metaverse and XR technologies. This course aims to equip beginning architecture design students in the graduate program, including students from non-design majors, with advanced digital skills while encouraging them to investigate innovative technologies and human-centered design solutions. The project addresses real-world challenges by incorporating interdisciplinary collaboration with industrial design students and local Kroger stores, enabling students to work on a conceptual design for the Future Retail Experience influenced by emerging technologies.

Design Process

Both studio courses followed a five-phase design process - research, system design, robot and space design, visualization, and validation - while adaptively applying the collaboration process and components laid out in the previous section. Among the four steps of the collaboration process, *learning*, *prototyping*, and *communication* were directly integrated into the design process. The research phase was a critical component of *learning* in collaboration, contributing to a shared understanding of the problems and framing them. Later in the design process, the visualization and validation phases represented both *prototyping* and *communication*, providing an opportunity to merge design outcomes from both disciplines, refine them, communicate proposed experiences and stories across disciplines and to the industry partner, and receive feedback.

Phase 1 - Research

The studio courses began with a collaborative research phase, where students worked in teams of three to examine the current state of retail services and environments, and identify insights for solutions. The research phase involved extensive investigation into consumer behavior, employee needs, current retail environments, emerging retail technologies, and case studies of innovative retail spaces. Students conducted on-site visits and interviewed staff and customers at local retail stores in Cincinnati, including Kroger, Whole Foods, Walgreens, and Target. In particular, the collaboration with Kroger allowed students to conduct in-depth interviews with store employees, providing insights from an employee perspective, such as item restocking and store management. Students were also asked to analyze and illustrate temporal and spatial task flows as two separate schematic diagrams, in which the current system elements and their correlations were arranged in the sequence of time and space. This analysis was intended to help students look into the whole system and recognize problems and opportunities as they connect this to their previous research. The research phase allowed students to establish a foundation for ideation, from which they proposed bold and forward-thinking concepts that reimagine how people interact with retail environments. More specifically, this phase encouraged students to frame their exploration around critical questions, such as:

- What might the future retail store look like in response to evolving consumer behaviors and Metaverse and XR technological advancements?
- How do online shopping and the increasing reliance on local store pickups reshape the architectural design of retail spaces?
- How can robots redefine the retail shopping experience while improving employee well-being?
- What challenges need to be addressed when introducing robots into the retail space?
- How can the metaverse and immersive technologies, such as VR and AR, create new opportunities for customer experience within retail environments?
- Can public, recreational, or community-oriented programs be integrated into retail spaces to enhance customer engagement and satisfaction?

Phase 2 – System Design

After identifying the real-world problems and target users, students explored ideas and developed initial concepts for robots, interfaces, stores, service elements, and other supporting artifacts that form a whole product-service system for a new retail experience from the systems thinking perspective. As various concepts were generated, special emphasis was placed on combining, refining, and organizing individual, fragmented ideas into system-level concepts that tell a cohesive story for a larger system. The outcomes in this phase, particularly from industrial design, were an organized collection of concept sheets, a storyboard, and a robot service blueprint.[19] These design tools helped students methodically ideate and visualize not only system components at the individual level but also their interrelationships and interactions within the broader product-service system.

Phase 3 – Robot and Space Design

In this phase, architecture students advanced their concepts into the schematic design stage, focusing on developing spatial layouts, circulation, 3D forms, structures, materials, and interactive technologies tailored to a real physical site or the virtual Metaverse. At the same time, industrial design students proceeded to configure the form, functional components, and structure of the robots, as well as user interfaces. This process involved defining the product architecture for the robot and the information architecture for the digital interfaces on and surrounding the robot, considering human factors, and developing the robot's detailed design through iterations of sketching, CAD modeling, and low-fidelity physical prototyping.

Phase 4 – Visualization

After completing the research and design stages, students moved to the visualization phase, employing various advanced tools and methods to bring their ideas to life. This included further development of CAD models, VR simulations, and digital renderings. Architecture students were introduced to free-form and parametric modeling processes such as Grasshopper and Rhino, while industrial design students used parametric solid modeling tools like Fusion360 and Solidworks. The visualization process in Twinmotion and Unreal engine enabled students to communicate their design intent effectively and gather feedback from peers, instructors, and industry collaborators. Commercial rendering engines were introduced for creating photorealistic concept renderings and animations. Architecture students utilized Twinmotion, Lumion, or Enscape, while industrial design students used Keyshot for high-fidelity renderings of robots and Blender for animations. Animations allowed students to visualize the operation, movement, and interaction of robots in the retail space and effectively communicate the comprehensive story for their design concepts. This exercise aimed to equip architecture students with essential skills in model preparation for metaverse development. To ensure the metaverse prototype functions effectively in VR, students focused on three key aspects: 1) the number of objects in the Metaverse, 2) polygon count per object, and 3) file size (e.g., FBX or Datasmith) and optimization process for the Unreal Engine. A dedicated teaching module included comprehensive lectures on the critical importance of scene optimization for VR devices. After importing their models into Unreal, students learned how to configure materials and lighting, explored various presentation media, such as animation, and designed interactive elements.

Phase 5 - Validation

The initial collaboration plan included VR prototyping, integrating CAD models of designed robots into virtual retail spaces, and testing interactions and experiences in the virtual environment. Previous studies have demonstrated the efficiency of using VR for architectural presentation[20 21] and its effectiveness in studying human perception and behavior in human-robot interaction thanks to its ability to provide immersive and realistic experiences.[22] However, the integration of robots and retail spaces in VR was not fully realized due to time constraints. The project's relatively large scope to consider an entire system and the subsequent heavy workload on students delayed the initially planned timeframe for the integration. Another hurdle was unfamiliarity with the software tools the other discipline was using. By the time both disciplines were ready to combine their respective design outcomes, students felt too burdened to complete the integration. Instead, they proceeded to finalize their designs separately. For the architecture studio, the validation phase involved using Unreal engine to create a VR-based prototype based on the feedback received during mid-term presentations and critiques by the industry partner, Kroger. Students were encouraged to refine their metaverse designs to address potential challenges and optimize user experience.

The validation phase concluded with a joint exhibition in the final week of the semester, where the final design outcomes were presented to the Kroger supermarket team and experts in relevant technologies from other colleges. Attendees viewed animations on TV screens illustrating future scenarios of a supermarket robot and its surrounding system. They also wore VR headsets to experience the proposed retail stores in the Metaverse. This final VR experience was intended to demonstrate a comprehensive and innovative vision of the future retail store, showcasing how the industry can respond dynamically to technological advancements and shifting consumer demands (Fig 2). The exhibition enabled the students to receive feedback grounded in real-world perspectives from the professionals, helping them validate their design solutions. It also served *communication* in the collaboration process by providing a space to share their work across disciplines and with industry professionals.

Fig 2. Final joint exhibition.

Project outcomes

The project developed solutions for a product-service system of a supermarket robot and retail stores. A use case scenario for the supermarket robot was visualized through an animation, utilizing high-fidelity CAD models of the robot and its associated system components. These components included supporting artifacts, interfaces, and the physical environment, all cohesively rendered to narrate the system's story (Fig 3).

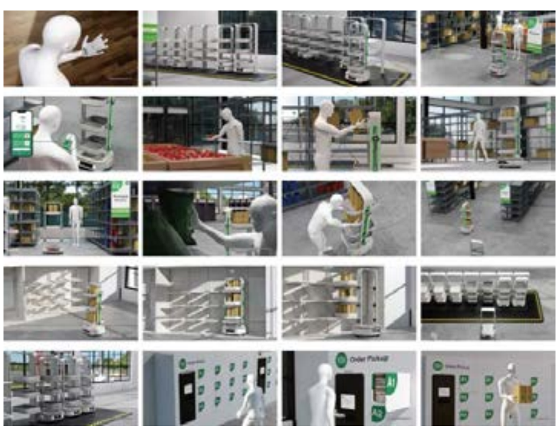

Fig 3. Animated scenario of a supermarket robot (work by Connor Rusnak, Cy Burkhart, and Kai Bettermann).

The industrial design student team redefined customer shopping experiences and employee workflows for grocery order fulfillment by introducing an automated grocery store system. This system consists of fulfillment robots working closely with human employees to collect and transport grocery items, robot hubs for recharging and restocking bins, automated storage/pick-up lockers for the drop-off and retrieval of fulfilled orders, and mobile devices with user interfaces for customers and employees. The proposed concept reconfigures traditional supermarket aisles into several fulfillment zones where employees pack and place grocery items onto robots' bins without a need for the employees to move across the store as the robots autonomously navigate along these zones according to individual orders the system receives.

The Walgreens metaverse begins with the core components of Walgreens stores, focusing on retail and pharmacy areas, each requiring unique redesign approaches (Fig 4).

Fig 4. Walgreen metaverse (work by Gavin Sharp, Isaiah Zuercher, and Thomas Lindenschmidt).

The redesign integrates autonomous features and telehealth services within the pharmacy, exploring concepts like Amazon-style pickup lockers and bank-style pneumatic tubes for dispensing medications. The proposed model includes over-the-counter retail area with automated checkout systems, allowing customers to scan and pay for items seamlessly. Additionally, it introduces pharmacy pickups through drive-throughs and walk-up lockers, and incorporates in-store telehealth booths for pharmacists to have real-time access via AR or VR. The plan further details transitioning from a non-autonomous to a fully autonomous pharmacy, enhancing pharmacists' roles in direct patient care and optimizing clinical programs.

This Kroger Metaverse envisions a reimagined Kroger grocery store in the Metaverse, transforming the traditional shopping experience into an immersive, futuristic, and engaging journey (Fig 5).

Fig 5. Kroger Metaverse (work by Varun Bhimanpally, Jahnavi Joshi, and Justin Hamilton).

Inspired by an actual Kroger store near the University of Cincinnati's uptown campus, the design optimizes space and efficiency by converting the ground-level parking lot into a public park and relocating the distribution center underground, taking advantage of the sloped terrain. The Kroger Metaverse integrates a user-friendly virtual interface featuring a mini-map for locating groceries and color-coded indicators, simplifying navigation and shopping. The interior blends nature-inspired aesthetics with innovative functionality, including a central “Mount of Greens” that simulates picking fresh produce in a forest, holographic displays, vertical cubbies for product catalogs, and seamless open spaces for exploration. Interactive elements, such as digital mascots to guide users and customizable vertical elevators, make the shopping experience dynamic and personalized. The vast open layout eliminates the constraints of real-life grocery stores, allowing free movement without the hassle of crowded aisles or broken carts. Beyond shopping, the space doubles as a multifunctional venue for concerts, seminars, or other activities, enhancing its appeal as a community hub. With its adaptability, modularity, and integration of interactive digital technologies, this Kroger Metaverse invites users into an innovative retail environment that combines utility, sustainability, and creativity, offering a memorable experience beyond the mundane task of buying groceries.

Discussion

Student learning outcomes

As TW Chan described regarding project-based, multidisciplinary learning, “to enable students to appreciate collaboration in a practical setting, multidisciplinary collaborative assignments can be integrated into AEC curricula.”[23] As students collaborated across disciplines, they applied systems thinking to conceptualize and prototype innovative solutions for new retail experiences leveraging emerging technologies. Students acquired a new perspective and skills to design a complex system holistically through the project by focusing on integrating products, services, and environments as well as physical and virtual elements. The design goal was not only to enhance user interaction and accessibility but also to create novel retail experiences for both customers and employees.

By following a structured system design process, students critically analyzed existing retail environments, identified problems and opportunities, and proposed forward-thinking solutions that improved operational efficiency and user experience. User-centered design was at the core of this project’s systems thinking approach and process, creating solutions emphasizing user engagement, personalization, employee well-being, and interaction between humans and emerging technologies. Additionally, students gained a deeper understanding of evolving trends in the retail industry, including the transformative potential of the Metaverse, XR, and robotics, better preparing them for future roles in design and innovation. These outcomes align with Gattupalli's assertion that "Metaverse offers architects a novel, unconstrained digital space to reimagine retail environments, enhancing brand-consumer interactions beyond traditional physical limitations."[24]

Pedagogy – opportunities and challenges

While traditional architectural theories and industrial design principles provided a strong conceptual basis, students also needed to adapt their learning to address practical challenges such as user experience, spatial integration, and technological feasibility. The participation of a supermarket chain in this project was invaluable, as it provided a bridge between academic learning and professional practice. Regular feedback and reviews of student presentations from industry professionals gave students insights into industry expectations, practical constraints, and consumer behavior, which are rarely covered in traditional curricula. This integration of real-world problems into the curriculum required careful planning and adaptation. Faculty needed to identify areas where theoretical knowledge could be applied to practical challenges while ensuring students maintained a deep understanding of core principles. Balancing these dual demands was complex and time-intensive, but the result was a more holistic learning experience that equipped students with the skills necessary for academic and professional success.

Interdisciplinary collaboration presents another substantial challenge in pedagogy, particularly when integrating diverse fields, such as architecture, industrial design, and emerging technologies like the Metaverse and robotics. These disciplines often have distinct pedagogical approaches, terminologies, and goals, making coordination and collaboration complex. Faculty had to encourage and facilitate cross-disciplinary work through multiple ways. Forming effective collaboration requires breaking down barriers between disciplines, fostering mutual respect, and promoting a shared vision. This often involves multidisciplinary teams, team-building activities, collaborative workshops, and structured peer evaluations to ensure close collaboration and productive group dynamics. However, as discussed earlier, such close collaboration in a cross-disciplinary team setting was not feasible in this study. Instead, the authors adopted alternative strategies to overcome this challenge, such as pre-planning, mutual learning through contextual research, prototyping, and various communication efforts. Particularly, the involvement of an industry partner and the joint exhibition were found effective in enhancing collaboration. As many cross-disciplinary collaborations face similar challenges, this approach can provide alternative means for collaboration and inspire design educators for novel approaches.

Despite these challenges, interdisciplinary integration in this study enriched the learning experience by exposing students to diverse perspectives and skill sets. Working collaboratively, students learned to communicate effectively, appreciate different approaches to problem-solving, and create innovative solutions that transcended disciplinary boundaries. While demanding, such collaboration prepares students for the increasingly interdisciplinary nature of real-world professional practice.

Conclusion

This paper examined a cross-disciplinary collaboration project between industrial design and architecture based on a systems thinking approach. The project explored how robotic systems can enhance store operations and customer experiences while introducing the Metaverse as an interactive platform for virtual retail spaces that transcend physical constraints. XR technologies were utilized to blur the boundaries between digital and physical retail, enabling augmented shopping experiences through mixed-reality interfaces. It is essential to understand the role of beginning design students in responding to challenges related to these emerging technologies and to reinforce spatial design, user experience, and technological integration in robot and Metaverse design through a systems thinking mindset. This collaboration underscores the importance of presenting a curriculum framework for teaching emerging technologies to meet the demands of rapidly changing academic fields. The findings contribute to the discourse on digital transformation in our physical world, offering insights into how architecture and industrial design can converge to redefine user experience for the future.

This study is not without limitations. The main limitation lies in its degree of cross-disciplinary collaboration. Logistical hurdles, such as conflicting class schedules, separate classroom locations, and differences in enrollment numbers between disciplines, created barriers to closer collaboration from the onset of the project. Discrepancies in course objectives, primary focus areas, and student expectations also made it challenging to align project timelines, ultimately preventing the integration of robot designs into virtual retail spaces for VR prototyping. We see a need to create a fully integrated collaborative course where students in both disciplines come to a shared space at the same class times. Although this entails more thorough planning for the course and the project between disciplines, it would enable closer collaboration. Additionally, this study is largely based on the observations of the authors who taught in the respective studio courses, which may introduce a degree of subjectivity. A future study is necessary to address this limitation. Collecting and analyzing student responses on their collaborative learning experiences and outcomes would provide a better understanding of this approach. A comparative study between a project conducted within a single discipline and one involving cross-disciplinary collaboration would also yield findings that are more scientifically grounded. Finally, participating students in this project were advanced in their design education, either in their fourth year of undergraduate studies or at the graduate level. This necessitates further studies and curriculum development to make this study's findings more applicable to beginning design students, who may lack the necessary design skills to tackle complex system-level problems.

Acknowledgment

The authors would like to thank Kroger for their invaluable support throughout this project.

End Notes

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ISBN: 979-8-218-76638-2
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