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A Study on Curriculum Reform for Age-Friendly Product Design Driven by Generative AI and Knowledge Graphs

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Abstract The accelerating pace of population aging has shifted the focus of age-friendly product design from a narrow product development issue to a comprehensive educational agenda encompassing user needs, social care, and the cultivation of design talent. As an interdisciplinary and practice-oriented course within the product design curriculum, “Age-Friendly Product Design” not only requires students to master the characteristics of elderly users, age-friendly design principles, and product evaluation methods, but also demands that they be able to translate this knowledge into concrete design solutions.Addressing issues in course instruction—such as fragmented knowledge structures, insufficient practical application, and weak process-based assessment—this study constructs a curriculum reform framework supported by the integration of generative AI and knowledge graphs. It uses knowledge graphs to optimize the organization of course content, leverages generative AI to facilitate the translation of design concepts into practice, and enhances process-based assessment through records of AI usage and the outcomes of phased assignments.Starting from the challenges of knowledge organization and practical application in age-friendly product design courses, this study elucidates the underlying logic of how generative AI and knowledge graphs synergistically support design instruction, providing a practical reference for collaborative reform in knowledge organization, design practice, and process evaluation within design courses at applied universities.

Keywords design for the elderly; generative AI; knowledge graphs; curriculum reform; design education

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1. Introduction

Population aging has become a critical issue in global social development. Results from China’s Seventh National Population Census show that the population aged 60 and older accounts for 18.70% of the total [1]. Against this backdrop, population aging continues to impact multiple sectors, including public services, healthcare, home life, and product innovation. Designing products for the elderly is no longer merely a matter of product aesthetics or functional improvements; rather, it has become a comprehensive design issue involving older adults' physiological functions, cognitive abilities, emotional needs, lifestyles, and social participation. Research by the World Health Organization on ageism also suggests that the design of products and services for older adults should avoid homogenizing or stereotyping them, and should instead emphasize the diversity of older users, their sense of dignity, and social equity [2].

The "Age-Friendly Product Design" course has distinct interdisciplinary characteristics; it requires students not only to understand the perceptual, cognitive, and behavioral changes in older users but also to master methods such as universal design, accessible design, ergonomics, user experience, product interaction, and usability evaluation. Existing research indicates that older adults' interactions with technological products are influenced by multiple factors, including vision, hearing, memory, attention, motor skills, and experiential background [3, 4]. Therefore, course instruction cannot be limited to theoretical lectures and case studies; rather, it should guide students through the complete design process—including user research, concept generation, design refinement, prototyping, and testing and evaluation—in real or quasi-real-world contexts.

From a pedagogical perspective, current courses on age-friendly product design still face issues such as fragmented knowledge points, insufficient practical application, inadequate feedback on the design process, and students' superficial understanding of older users. This indicates that an effective connection has not yet been established between the organization of course content, support for design practice, and assessment mechanisms. Design education emphasizes making comprehensive judgments in the face of uncertain problems; the development of design competence relies on problem identification, visual reasoning, iterative trial and error, and contextual reflection [5, 6]. If course content is not systematically organized, students tend to memorize topics such as gerontology, human-machine dimensions, interactive interfaces, materials and processes, and evaluation criteria as isolated concepts, making it difficult for them to apply this knowledge comprehensively in specific design tasks.

In recent years, the application of generative artificial intelligence in higher education has garnered widespread attention. Relevant research indicates that generative AI can offer new pedagogical possibilities in content generation, personalized learning, feedback support, and human-computer collaboration, but it also poses risks such as academic integrity issues, fabricated content, algorithmic bias, and excessive student reliance [7-9]. At the same time, knowledge graphs—as a structured method of organizing knowledge—can present course concepts, knowledge relationships, learning paths, and resource nodes in a networked format, thereby supporting personalized learning and the understanding of knowledge connections [10,11]. Therefore, integrating knowledge graphs with generative AI into the design of courses on age-friendly product design can help address the course's shortcomings in knowledge connections, practical support, and process-based assessment.

2. Course Background and Reform Needs

2.1 Course Characteristics

"Age-Friendly Product Design" is an integrated practical course offered to upper-level students in the Product Design program. Centered on older adult users, the course requires students to complete innovative product designs for scenarios such as home living, health management, mobility assistance, rehabilitation training, information interaction, and emotional companionship, based on an understanding of older adults' physiological, psychological, behavioral, and social contexts. Compared to general product design courses, the complexity of this course is primarily reflected in three aspects.

First, the course content is interdisciplinary. Designing products for older adults requires the integration of knowledge from gerontology, ergonomics, user research, accessible design, interaction design, materials and manufacturing, and emotional design. Recent research on age-friendly technology and inclusive design indicates that product development for older adults cannot be driven by a single function alone; instead, it must simultaneously consider multiple factors such as users' physical capabilities, cognitive characteristics, living environments, social support, and level of technological acceptance [12]. This requires students not only to focus on a product's appearance and form but also to understand the real limitations older users face in perception, comprehension, operation, maintenance, and sustained use, and to be able to translate knowledge from different disciplines into concrete design decisions.

Second, the course assignments are highly practical. Students must start with real-world problems and go through stages such as needs identification, user profiling, problem definition, concept generation, solution screening, prototyping, and usability evaluation. Recent research in design education emphasizes that product design learning should not be limited to knowledge transmission and conceptual expression; rather, it should foster students' design capabilities through contextual tasks, project-based practice, tool application, and reflective iteration [13]. At the same time, the application of interactive technologies, computational intelligence, and digital tools in product design education is transforming the ways in which students conduct design research, generate solutions, and present their work [14]. Therefore, the instructional focus of this course should shift from "knowing the principles of age-friendly design" to "being able to apply these principles in real design processes."

Third, the course content embodies a humanistic approach and is tailored to the needs of older adults. Age-friendly product design addresses the needs of older adults, whose physical functions, sensory abilities, and cognitive capacities may change over time. During the design process, students must not only focus on whether a product's functions are complete and its form is aesthetically pleasing but must also prioritize whether the product aligns with older adults' actual physical conditions, lifestyle habits, and usage capabilities. They must then translate these requirements into specific design decisions regarding dimensions and proportions, grip methods, button recognition, information prompts, operating procedures, and maintenance methods. Relevant research indicates that the design of senior-friendly and assistive products must be grounded in older adults' preferences, varying abilities, and actual usage scenarios to avoid product underutilization or usability barriers resulting from insufficient design assumptions [15]. Contextual co-creation research also suggests that only by involving older users and relevant stakeholders in problem articulation and solution development can their genuine needs and emotional appeals be more accurately understood [16].

2.2 Existing Teaching Issues

During the initial curriculum review, the research team analyzed course syllabi, past student assignments, student interviews, and course evaluation records to identify three major issues in the course's teaching prior to the reform:

First, the course's knowledge framework was relatively fragmented, leading to a lack of systematic understanding among students. Age-friendly product design involves a wide range of disciplines, including gerontology, ergonomics, user research, accessible design, interaction design, materials and manufacturing, and product evaluation, making it highly interdisciplinary. However, in traditional teaching, related content was often presented in the form of individual chapters or topics, resulting in unclear logical relationships and application pathways between knowledge points. Although students could understand some concepts and principles, they struggled to connect the characteristics of older users, usage scenarios, product functions, interaction methods, and evaluation criteria. This often led to a fragmented understanding, which in turn affected their subsequent design decisions.

Second, there is insufficient translation of course theory into practice, and students' ability to generate design solutions needs improvement. While some students can articulate the principles of age-friendly design at a theoretical level, they still struggle to accurately identify the genuine needs of older users in specific design tasks and to determine whether functional settings, structural forms, and operational workflows are appropriate. Some projects prioritize visual presentation over usage scenarios and conceptual creativity over safety and accessibility, resulting in design solutions that fail to adequately align with older users' physical capabilities, cognitive characteristics, and daily living contexts. This indicates that the course needs to provide more continuous instructional support in areas such as user research, problem definition, solution comparison, prototype refinement, and presentation optimization.

Third, course evaluation has tended to focus on final outcomes while paying insufficient attention to the learning process. In the past, course evaluations have largely centered on end-of-term project presentations, design briefs, and the effectiveness of presentations, with insufficient attention given to students' learning processes in problem identification, data analysis, solution iteration, tool usage, and reflective summaries. This is particularly true now that generative AI has been integrated into design education; without necessary usage logs and process tracking, instructors find it difficult to assess students' actual thought processes and changes in their abilities. Therefore, course assessment must shift from a single-outcome orientation to an evaluation approach that combines process documentation, stage-based outcomes, and reflective improvement, in order to more accurately reflect students' learning engagement, design reasoning, and solution optimization abilities.

3. Curriculum Reform Design Integrating Generative AI and Knowledge Graphs

3.1 Overall Framework for Reform

This study adopts the integrated application of generative AI and knowledge graphs as the primary pathway for curriculum reform, constructing a teaching framework centered on "curriculum knowledge reorganization, AI-assisted design, project-based tasks, and process-based evaluation feedback." Starting from the reorganization and practical application of curriculum knowledge, this framework uses knowledge graphs to map out core concepts, knowledge nodes, methodological pathways, and competency requirements within the curriculum. This creates a clear, interconnected structure linking content such as the characteristics of older users, age-friendly design principles, ergonomics requirements, interaction flows, materials and processes, and evaluation criteria. Building on this foundation, generative AI is further integrated into teaching phases such as user research, problem definition, concept generation, proposal refinement, evaluation feedback, and presentation of outcomes, providing students with support in organizing information, expanding their thinking, comparing proposals, and optimizing their presentations.

In practice, knowledge graphs are primarily used to visualize the hierarchical, sequential, and applied relationships among course concepts, helping students understand how different elements of knowledge interact within the age-friendly product design process. For example, vision deterioration in older users can be linked to interface information hierarchy, color contrast, font size, and visual accessibility evaluations; decreased hand strength can be further linked to grip dimensions, operational damping, product weight, and safety requirements. Generative AI, based on these knowledge associations, assists students in retrieving knowledge, generating preliminary proposals, and conducting proposal evaluations for specific project tasks. In this process, instructors play a role in providing professional judgment and value guidance, ensuring the authenticity, age-friendliness, feasibility, and ethical boundaries of AI-generated content; Project tasks serve as practical vehicles, integrating knowledge graphs and generative AI into real or quasi-real aging-friendly product design scenarios, thereby facilitating students' learning transformation from knowledge comprehension to proposal generation, and from proposal presentation to iterative optimization. Consequently, the curriculum reform forms a closed-loop system characterized by "knowledge graphs organizing knowledge, generative AI supporting practice, project tasks facilitating the process, and teacher evaluation ensuring quality."

3.2 Constructing the Course Knowledge Graph

Knowledge graphs organize complex knowledge through nodes, relationships, and hierarchical structures, helping to reveal the intrinsic connections between course concepts while supporting the retrieval of learning resources, the recommendation of learning paths, and the management of course content. The knowledge graph for this course consists of knowledge nodes, relationship types, resource links, task mappings, and evaluation metrics, forming a structured knowledge system. Relevant research indicates that knowledge graphs in the field of education have been widely used in scenarios such as concept association construction, personalized learning support, curriculum design, and educational resource recommendations [17]; simultaneously, transforming educational materials into knowledge graphs also helps enhance the structured representation of learning content, knowledge navigation, and learning recommendation capabilities [18].

Based on this, the construction of the knowledge graph for this course primarily involves five steps. First, organize knowledge sources, including course syllabi, textbook content, teaching presentations, exemplary assignments from previous semesters, case studies of age-friendly products, accessibility design standards, and corporate project materials. Second, extract knowledge nodes by dividing the course content into five modules: cognitive abilities of older users, principles of age-friendly design, product interaction design, material structure and craftsmanship, and design evaluation and iteration. Third, relationship types were defined, including inclusion, precondition, application, evaluation, and extension relationships. Fourth, through course team discussions and reference to industry case studies, the classification of knowledge nodes, relationship definitions, and application paths were refined based on instructional objectives, student assignment performance, and the practical development needs of age-friendly products, thereby enhancing the alignment between the knowledge graph and course assignments. Fifth, node content is continuously updated based on student learning feedback and project outcomes. The number of knowledge nodes was determined based on the course syllabus, teaching materials, and project task breakdown, and was revised following discussions by the course team.

This course ultimately comprises 5 thematic modules, 38 knowledge points, and 146 knowledge nodes, all of which are mapped to course assignments, learning resources, and evaluation metrics. The purpose of the knowledge graph is not to pursue complex technical implementation, but to help students clearly understand the interconnections between the characteristics of older users, design principles, product functions, interaction details, and evaluation metrics, thereby preventing students from losing sight of the course's overall logic amid fragmented learning. For example, visual impairment can be further linked to nodes such as information hierarchy, font size, color contrast, and visual accessibility evaluation, thereby forming an application pathway that extends from user characteristics to design details and ultimately to evaluation metrics. Through this structured organization, students can more accurately apply relevant knowledge to specific design tasks and understand how different knowledge elements interact within the design process for age-friendly products.

Table 1 Content of the Knowledge Map for the Age-Friendly Product Design Course

Module	Knowledge Points	Corresponding Design Tasks	Key Competencies to Be Developed
Understanding Older Users	Physical decline, cognitive changes, emotional and social needs, lifestyle	User Profiling and Needs Analysis	User Research Skills
Principles of Age-Friendly Design	Universal Design, Accessible Design, Accessibility Principles, Safety Requirements	Extraction of Design Principles and Evaluation of Design Proposals	Design Judgment Skills
Product Interaction	Information Hierarchy, Workflows, Feedback Methods,	Interaction Flow Optimization	Interaction Design Skills

Design	Cognitive Load		
Materials, Structure, and Manufacturing Processes	Material Texture, Ergonomic Dimensions, Structural Stability, Ease of Maintenance	Concept Development and Prototyping	Structural and Prototyping Skills
Design Evaluation and Iteration	Usability Testing, Age-Friendly Evaluation, Ethical Review, and Design Review	Prototype Testing and Iterative Optimization	Testing, Evaluation, and Iteration Skills

3.3 Generative AI-Assisted Teaching Resources and Design Process

In the "Age-Friendly Product Design" course, the application of generative AI must be integrated with course content, design tasks, and the development of students' competencies; it cannot be limited to tool demonstrations or simple content generation. The curriculum reform incorporates AI tools into the teaching framework, enabling them to support pre-class learning, in-class exercises, and post-class extensions, while also engaging students throughout the entire design process—from user research to the presentation of final outcomes.

To support the application of generative AI in the course, the teaching team has developed resources such as prompt templates, case study materials, phased task sheets, AI usage logs, and age-friendly evaluation checklists, ensuring that AI tools align with course objectives, learning tasks, and formative assessment. Specifically, prompt templates are primarily used for creating user personas, designing interview outlines, summarizing needs, brainstorming solutions, and refining design descriptions; case studies illustrate effective pathways for AI-assisted design, common pitfalls, and methods for correction; stage task sheets clarify learning objectives, tool usage requirements, and submission standards for each teaching phase; and AI usage logs require students to document their input, generated results, selection criteria, and revision processes. For example, during the user research phase, prompt templates guide students to develop interview questions focused on elderly users' visual and auditory abilities, manual dexterity, and daily usage contexts, and to refine these questions based on real research data. Through these resources, AI usage is integrated into the course training system, enabling students to engage in learning and design practice within clearly defined task boundaries and evaluation requirements.

In the design process, generative AI is primarily involved in stages such as user research, problem definition, concept generation, proposal refinement, presentation of outcomes, and evaluation feedback. The course guides students to select appropriate tools based on different tasks, including text-generation tools such as ChatGPT, Wenxin Yiyan, and Tongyi Qianwen, as well as image-generation tools such as Midjourney and Stable Diffusion. Text-generation tools are primarily used for organizing research findings, summarizing requirements, comparing solutions, and optimizing copy, while image-generation tools are mainly used for conceptual brainstorming, scenario visualization, and visual exploration. The course does not require students to use all tools simultaneously at every stage; rather, they are encouraged to select appropriate AI-assisted methods based on the type of task. The entire process emphasizes "knowledge retrieval—AI assistance—human curation—solution iteration," requiring students to assess the validity of AI-generated content based on knowledge graphs and to refine their proposals under faculty guidance. This process underscores that AI outputs are not final answers but rather intermediate materials for design reasoning, solution comparison, and human judgment.

Table 2 Application Themes of Generative AI in the Teaching Process for Age-Friendly Product Design

Application Themes	AI Tools	Student Tasks	Instructor Guidance
Needs Insight and User Understanding	Use ChatGPT, Wenxin Yiyan, and Tongyi Qianwen to assist in generating interview outlines, user personas, and a needs classification framework.	Design interview questions and organize the characteristics, pain points, and usage scenarios of elderly users.	Verify the authenticity of the needs sources and correct generalized or stereotypical understandings of elderly users.
Problem Definition and Opportunity Identification	ChatGPT and Tongyi Qianwen categorize research data to identify pain points, usage barriers, and design opportunities.	Define core design questions, establish requirement priorities, and determine design directions.	Determine whether problems stem from real-world scenarios to avoid inventing needs out of thin air or over-broadening the scope of the problem.
Conceptual Brainstorming and Visual Exploration	Use Midjourney and Stable Diffusion to generate reference images of product forms, usage scenarios, and mood boards, while ChatGPT assists in establishing criteria for comparing design proposals.	Develop multiple sets of functional paths, interaction methods, and visual concepts, and complete an initial screening.	Guide students to evaluate the age-friendliness, innovativeness, scenario fit, and potential for further development of the proposals.
Solution Refinement and Age-Friendly Evaluation	Use ChatGPT and Wenxin Yiyan to review operational steps, information prompts, visual accessibility, ease of maintenance, and potential risks based on an	Optimize product features, interaction flows, and structural details, and document the iteration history of the proposals.	Assess the feasibility, safety, ethical risks, and dignity of elderly users when using the solution.

Application Themes	AI Tools	Student Tasks	Instructor Guidance
	age-friendly evaluation checklist.		
Presentation of Results and Reflective Iteration	ChatGPT, Wenxin Yiyan, and Tongyi Qianwen assist in optimizing the structure of the design report, exhibition panel copy, and presentation logic, while documenting the AI usage process.	Complete the design report, exhibition board displays, and AI usage instructions, and submit a reflection record.	Monitor compliance with academic standards and originality requirements, and evaluate students' ability to access knowledge, make informed judgments, and refine their proposals.

3.4 Formative Assessment Mechanism

To standardize the use of generative AI in the course, this course extends the evaluation focus from end-of-term outcomes to the entire design process, emphasizing students' actual performance in user research, problem identification, AI utilization, proposal screening, and iterative optimization. Evaluation materials include user research data, records of prompt modifications, explanations for the selection of AI-generated content, records of proposal optimization, project evaluation forms, and learning reflection logs. After completing each stage of the assignment, students must submit a record of their AI usage, explaining the purpose of use, changes to the prompts, the criteria for selecting or rejecting generated results, and any manual modifications made. Through these formative materials, instructors can determine whether students have genuinely understood the relevant knowledge nodes in the knowledge graph and whether they can transform AI-generated content into effective design decisions, rather than merely relying on the tool to quickly generate text and image outputs.

To enhance the practicality of process-based assessment, the course divides evaluation criteria into five dimensions: user research and problem definition, knowledge graph utilization, AI usage and filtering, proposal refinement and iteration, and presentation of outcomes and reflection.

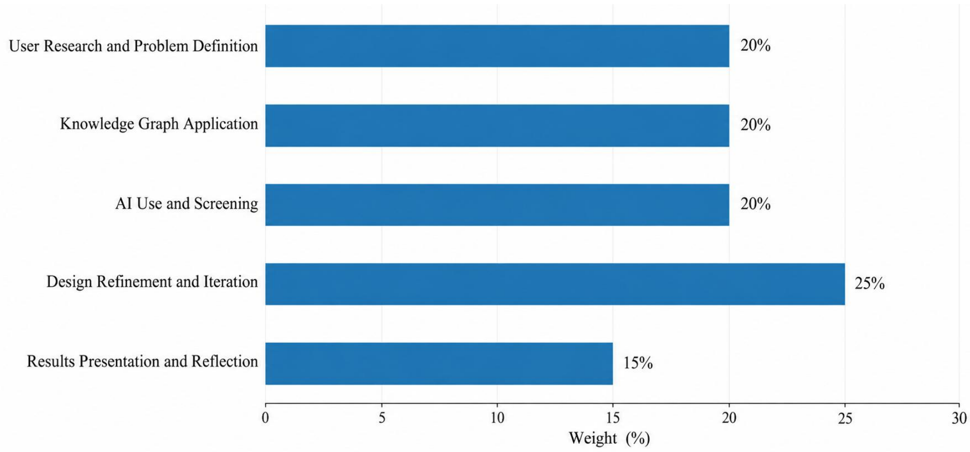

Figure 1 Weight Distribution for Formative Assessment in the Age-Friendly Product Design Course

The focus of formative assessment is not to increase the assessment burden, but to guide students in developing clear design thinking and a sense of responsibility regarding AI use. Based on the process records submitted by students, instructors should promptly identify issues in needs analysis, age-friendly design assessments, solution feasibility, and presentation logic, and provide phased feedback. For AI-generated content containing fabricated information, excessive embellishment, unrealistic usage scenarios, or insufficient age-friendly design, instructors need to guide students to revisit user needs and the course's knowledge framework to make corrections. At the same time, when using AI tools to process user data, students should avoid entering personally identifiable information and should anonymize interview transcripts, photographs, and user feedback to reduce the risk of privacy breaches and ethical violations. Research on formative assessment indicates that continuous feedback helps improve students' learning attitudes and performance [19]. Research on AI education also suggests that instructors need to assume clearer guidance responsibilities in areas such as learning support, feedback design, academic integrity, and ethical management [20, 21]. Therefore, this course incorporates AI usage, design iterations, and learning reflections into a single assessment chain through formative assessment, promoting a shift from outcome-oriented completion to competency development.

3.5 Teaching Practices and Application Feedback

In course implementation, the integrated application of generative AI and knowledge graphs is primarily advanced through phased assignments. The application feedback in this section is primarily derived from classroom observations, student assignments, AI usage logs, and learning reflection texts, and is used to present typical performance patterns and areas for improvement during course implementation. In the early stages of the course, instruction centered on knowledge graph-based guided learning. The instructor guided students in understanding the interrelationships among the characteristics of elderly users, principles of age-friendly design, ergonomic requirements, interaction flows, and evaluation criteria, helping students establish a basic knowledge framework. Upon entering the project phase, students identified design themes centered on scenarios such as home life, health management, mobility assistance, rehabilitation training, information interaction, and emotional companionship, and accessed relevant knowledge nodes based on project requirements. Generative AI is utilized in various stages, including the creation of interview outlines, the organization of user personas, the synthesis of user needs, concept brainstorming, proposal evaluation, and the presentation of final outcomes. Instructors set checkpoints at each stage to assess whether students are formulating questions based on authentic research data, whether they can justify their selection of AI-generated content, and whether they can further transform AI outputs into design proposals that meet age-friendly requirements.

Feedback on the pedagogical application indicates that knowledge graphs help students grasp the logical relationships between course content more clearly, reducing the tendency to merely memorize concepts without knowing how to apply them.

Student feedback indicates that generative AI provided additional conceptual support during the early stages of research organization and brainstorming, making it easier for them to develop multiple design directions and conduct preliminary comparisons. At the same time, teaching practice has also revealed some issues that require continuous improvement. For example, some students tend to treat AI-generated user personas as genuine user needs or rely excessively on image-generation tools to create superficial solutions; while some students are able to produce relatively comprehensive design descriptions, they lack sufficient judgment regarding the structural feasibility and age-friendly risks of their proposals. Therefore, future instruction should place greater emphasis on real-user interviews, low-fidelity prototype testing, and age-friendly design checklists, while further strengthening the review of AI outputs, design ethics, and phased feedback, so that generative AI truly serves to enhance students' design judgment and skill development.

4. Conclusion

This study addressed issues such as a fragmented knowledge system, insufficient practical application, and weak process-based assessment in the "Age-Friendly Product Design" course, exploring specific pathways for course reform supported by the integration of generative AI and knowledge graphs. The study concludes that the "Age-Friendly Product Design" course is distinctly interdisciplinary, practical, and rooted in humanistic care. Relying solely on traditional lectures and end-of-term project evaluations makes it difficult to effectively support students' systematic understanding of elderly users' needs, age-friendly design principles, product interaction details, and evaluation criteria for design proposals. By constructing a course knowledge graph, the previously fragmented course content can be transformed into a knowledge network characterized by hierarchical, sequential, and applied relationships, helping students understand the roles of different knowledge points in the design process. The integration of generative AI further expands the ways in which students are supported during user research, problem definition, concept generation, proposal refinement, and presentation of outcomes, providing assistance with organizing materials, brainstorming solutions, and conducting preliminary evaluations. The combination of these two approaches ensures that curriculum reform goes beyond mere tool usage, instead forming a teaching model grounded in knowledge structure, driven by design tasks, and supported by intelligent assistance.

From the perspective of course implementation, the combination of generative AI and knowledge graphs helps drive the "Age-Friendly Product Design" course toward a shift from knowledge-based instruction to competency-based learning. On the one hand, knowledge graphs enable students to retrieve relevant knowledge more accurately during design practice, reducing reliance on isolated experiences and superficial concepts; on the other hand, generative AI provides students with richer pathways for proposal generation, expression optimization, and feedback-based revisions, though its use must be grounded in faculty guidance and formative assessment. Particularly in age-friendly product design, AI-generated content may suffer from insufficient demand assumptions, unrealistic usage scenarios, and inadequate assessments of age-friendliness; therefore, instructors must continue to ensure authenticity, feasibility, ethical standards, and humanistic considerations. The value of generative AI lies not in replacing students in completing design tasks, but in fostering students' problem-awareness, knowledge integration skills, solution iteration capabilities, and critical judgment skills. Future research could further expand the course sample size and refine the evaluation of learning outcomes by utilizing multi-source data—such as questionnaires, interviews, project evaluations, and records of learning behaviors—while integrating real-world corporate projects and testing with elderly users to continuously optimize the teaching model for AI-assisted senior-friendly product design courses.

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