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collaborative settings, transform teaching, learning processes and dynamics, influence decision-making, knowledge sharing, productivity, innovation and engagement, impact learning, how questions are asked, decisions are made, skill development, social interactions unfold, motivate the creation of open-source, social learning processes

Generative AI in Collaborative Learning Environments

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Contents | Indhold

academic quarter
akademisk kvarter
research from the humanities
AAU

Volume 31. Autumn 2025

Generative AI in Collaborative Learning Environments

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Keywords: generative AI, learning processes, collaborative practices, socio-materiality, computer-supported collaborative learning

Both potentials and concerns related to generative AI in education have been heavily discussed, particularly since the launch of ChatGPT towards the end of 2022. Potentials to improve students' learning experiences through interactions with AI have for example been emphasized while academic integrity has been a central concern. However, much of this discussion has centred on the individual (Sharples 2023); the individual student's or teacher's interaction with a chatbot, the individual student's potential "cheating" at exams, and the individual student's need for AI literacy. In this context, collaboration has often been understood to refer to human-AI collaboration, i.e. collaboration between an individual and AI, not collaboration between humans while interacting with generative AI. However, generative AI has been argued to have the potential to contribute to the "social learning process of setting shared goals, performing tasks together, exploring possibilities, and conversing to reach agreements" (Sharples 2023). Through this special issue of Academic Quarter, we have aimed to direct attention specifically towards the dynamics when generative AI is integrated in such collaborative learning environments.

Empirical research in this area is surprisingly scarce. In the following, we highlight three exemptions, all conducted within the context of higher education. Firstly, Perifanou and Economides (2025) explore student teams' use of generative AI in project work. They find that, as opposed to e.g. independently developing prompts and then discussing their respective outputs, students prefer a working mode where they collaborate on iteratively generating and revising prompts and on evaluating output, finding that this provides a shared discussion space and supports a collective way of thinking. Secondly, Law et al. (2025) explore how generative AI mediates knowledge building in an extra-curricular hackathon setting where students work in teams. They conceptualize AI literacy as part of digital competence and e.g. explore which roles GAI tools play in a knowledge building process. Drawing on a large dataset of pre- and post-surveys, interim reports and workspace logs, they find that generative AI facilitates collaborative, inquiry-driven learning. Students for instance used generative AI tools for ideation, to understand technical concepts, to develop and debug prototypes as well as for presentations and website development. The teams also highlighted how they engaged in iterative dialogue

with generative AI and negotiated understanding. Thirdly, Kaup et al. (2025) explore how generative AI can support collaborative learning in higher education, specifically when students work with course literature. Drawing on class interactions, focus group interviews and prompt logs, the authors find that when used as a mediating artefact, generative AI leads to student-to-student dialogues around prompts and AI output. In this way, their interaction with the literature is supported, and this seems to extend their understanding of the literature and its concepts.

In the call for papers for this issue, we solicited contributions providing us with more insight into how generative AI unfolds in collaborative learning environments, suggesting a computer-supported collaborative learning (CSCL) and socio-material perspective. In the following, we will introduce these theoretical frameworks as well as introduce the contributions of the issue.

Generative AI, Socio-Materiality and Computer-Supported Collaborative Learning

Orlikowski and Scott (2008) consider socio-materiality as a palette of approaches that may advance the way we study technology, work, and organizations, by moving beyond analytical separations between humans and technologies and instead foregrounding how work practices are constituted through their ongoing socio-material entanglements. In learning contexts, CSCL can serve as a framework for examining the materiality of socio-material dynamics, as CSCL emphasizes how technology supports collaboration and learning. The socio-material perspective, in combination with CSCL, makes it possible to shed light on material aspects of collaboration that would otherwise have been overlooked in the shadow of human interaction. This perspective opens a deeper understanding of how technology's material and digital dimensions not only support, but also actively shape collaborative processes. In the context of CSCL, this means exploring how technologies like generative AI function not just as neutral tools, but as actors that influence and transform the human-technology dynamic.

CSCL investigates how collaborative learning can be intentionally designed and supported so that technology enriches the interactions that drive learning. It brings together instructional design and learning technologies to enable guided, purposeful collabora-

tion across diverse pedagogical contexts from small groups working on short, structured tasks to large online communities sharing knowledge over long periods. CSCL considers a broad range of tools, from basic communication platforms to specialized systems that scaffold specific collaborative processes, all aimed at weaving technology-supported collaboration meaningfully into educational practice (Dillenbourg and Fischer 2007).

Recently, generative AI has been embedded into education and workplace practices, affecting learning activities in a variety of ways. As mentioned above, its impact on collaboration has received limited attention, including how it mediates interaction, supports shared understanding, and changes the social dynamics of learning altogether. This special issue addresses this gap by examining generative AI through a CSCL lens and its role in collaborative learning dynamics, regardless of whether the work is coordinated individual work (cooperative) or work involving shared goals and mutual interdependencies (collaborative) (Bang and Dalsgaard 2005).

Contributions to the special issue

The issue comprises six articles which have all explored the topic within formal educational settings, ranging from primary school to higher education. The contributions give us interesting insights into different disciplinary settings, different uses of generative AI and different levels of scaffolding of collaborative activities.

In the first article of the issue, *Fostering Creativity and Self Efficacy Through Collaborative Learning Using Generative Artificial Intelligence (AI) in the Product Design Visualization Process*, Mohamed Kamil et al. explore how generative image models can be integrated into product design students' visualization processes. Their findings show that these tools significantly enhance students' creativity and self-efficacy while strengthening collaborative learning dynamics. The study highlights the transformative potential of generative AI in product design education, positioning it as an active co-creator within both learning and design practices.

Next, in the article *AI-Aided Collaborative Design in Industrial Design Education for Final Year Projects (FYP): Improving Workflow and Innovation,* Me et al. study how AI-assisted tools shape creativity, collaboration, and workflow efficiency among final-year Industrial Design students. Drawing on a mixed-methods comparison be-

tween an AI-supported class and a traditionally taught class, the study shows that integrating AI across research, ideation, simulation, reporting, and prototyping leads to higher creativity and stronger design outcomes. The authors argue that AI works best as a creative partner when paired with a human-centered learning approach that preserves students' critical thinking, originality, and ethical responsibility.

In another disciplinary context, Meyer and Gregersen, in their article *Collaborative language learning through generative AI: the case of French,* investigate the ways in which generative AI becomes part of and influences the collective learning processes of the French language in Danish public schooling. Inquiring into the rhythms of such socio-material entanglement by interviewing preservice teachers, observing classroom teaching, and analysing learning materials, the authors find that generative AI contributes to the students' agency in language learning.

Kaup et al., in their article *Transformative AI Agency: how Students Negotiate and Collaborate with Generative AI in Higher Education,* explore collaborative practices through lenses of cultural-historical activity theory. During a case study of an elective course where students in pedagogically scaffolded activities explored literature using ChatGPT, the authors collected audio recordings, prompts and response logs from ChatGPT, written reflections, and performed focus group interviews with students. The authors find that scaffolded and planned teaching activities can promote critical engagement and collective reflection when using ChatGPT as a mediating artefact.

Next, Jensen et al., in their article entitled *Ethical Implications of Generative AI in Collaborative Learning for Decision-Making in Circular Construction,* explore how students in a circular construction course navigate the role of generative AI in early-stage collaborative design processes. They do so drawing on an exploratory case study of students working in interdisciplinary teams. They conducted focus groups interviews with four groups and adopted a socio-material perspective. The authors find that, in these design processes that are characterized by value-laden trade-offs, generative AI contributes to creative ideation. Based on the finding that generative AI influences which ideas gain legitimacy, and how knowledge is mobilised, the authors argue that generative AI reconfigures epistemic

authority in collaborative processes. The students also point to a need for source verification when working with generative AI and to issues of accountability and transparency.

Finally, in *Artificial Intelligence-Generated Vignettes as Triggers for Reflection: Exploring Methodological Potentials in Higher Education,* Kaup et al. investigate how generative AI may be used to foster collaborative reflection and judgement in education. Prompting generative AI to produce realistic albeit fictional scenarios of everyday practices for social educators, the authors analyze how video vignettes can support students' collaborative reflections in relation to the authentic and real-world dilemmas addressed in the vignette. The authors find vignettes to be a valuable pedagogical tool when including ethical and moral deliberation and professional judgement, often part of professional practice. Further, Kaup et al. find the vignettes to support collective reflective processes.

Conclusion

Our intention with this special issue has been to give attention to the collaborative settings where generative AI is deployed and to the socio-material dynamics this entails. The contributions have addressed this in different formal educational settings and have helped shed valuable light on potentials and limitations of generative AI. In the coming years, we should maintain a focus on not only human-AI collaboration in education, but also what we might call human-AI-human collaboration, cultivating learning environments that leverage the potentials of generative AI in collaborative contexts while mitigating risks as to the learning process.

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Volume 31. Autumn 2025

Fostering creativity and self-efficacy through collaborative learning using generative Artificial Intelligence (AI) in the product design visualization process

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Abstract

Generative models in Artificial Intelligence (AI) are increasingly employed across diverse fields, including product design, for tasks like shape recognition and design creation. This trend underscores generative models' ability to bridge offline and online environments in creative endeavors. The article investigates the potential of

integrating generative image AI into visualization process among product design students. Using image-based research analysis and semi-structured interviews, this study involved 50 product design students as respondents. The findings highlight that integrating generative AI tools, particularly the ChatGPT 4.0, significantly improves students' creativity and self-efficacy through collaborative learning, and streamlines the design process. The findings also close the gap between creative concepts and practical applications, and offers a robust framework for evaluating AI-generated content. The contribution of the study underscores the transformative potential of generative AI tools in product design education, showcasing the effectiveness in fostering creativity, efficiency, and design quality through collaborative learning.

Keywords: Artificial Intelligence; Product Design; Creativity; Self-Efficacy; Collaborative Learning

Introduction

Generative Artificial Intelligence (AI) has transformed content creation by producing realistic text, images, audio, and video through pattern learning rather than rule-based programming (Ye et al. 2024). Tools such as Stable Diffusion and DALL-E now enable high-quality visual generation from simple text prompts, lowering the need for artistic or technical skills. Likewise, large language models like GPT extend AI's role in reasoning, communication, and design-related tasks (Tian et al. 2024). Generative AI also reduces technical barriers and opens new opportunities for creative innovation (Hashmi and Bal 2023). In product design education, generative AI has the potential to reshape ideation practices. The discipline emphasizes competencies such as design thinking, user research, ergonomics, prototyping, and user experience (Huang et al. 2024; Mohamed Kamil and Abdullah Sani 2021). These align with the four stages of design thinking: (1) empathy, (2) define, (3) ideation, and (4) prototyping and testing. The ideation phase is especially crucial because it encourages divergent thinking and conceptual exploration (Jonson 2005; Self, Evans, and Kim 2016; Nelson et al. 2009; Chien et al. 2022; Mohamed Kamil et al. 2024). Traditionally, ideation relies on hand-drawn or digital sketches, which may be limited by time constraints and individual drawing ability. Integrating gen-

erative AI into ideation introduces new possibilities for co-creation, allowing rapid translation of concepts into visual outputs (Huang et al. 2024). This accelerates idea exploration and supports self-efficacy as students interact with AI as a responsive partner that provides instant feedback. Crafting precise textual instructions (prompt engineering) is essential to align AI-generated visuals with design intent and ethical considerations (Short and Short 2023; Tian et al. 2024). Within collaborative learning settings, AI can function as both a creative stimulus and a pedagogical tool that connects imagination with visualization. This study examines the use of generative image-based AI in the ideation phase of product design education. It explores how AI affects students' creative outputs and self-efficacy when used within a structured collaborative environment. The research focuses on two objectives: (1) to evaluate the direct influence of generative AI on the creativity and variety of student-generated design visuals; and (2) to assess its indirect impact on self-efficacy and creative confidence through collaborative learning. These aims contribute to theoretical and pedagogical insights on integrating AI into design education to enhance creativity, collaboration, and learner confidence.

Collaborative Learning

Collaborative learning is grounded in sociocultural theory, which views knowledge as co-constructed through interaction and scaffolding within shared problem spaces (Vygotsky 1978). It involves learners working jointly to build understanding or generate solutions (Dillenbourg 1999). The cooperative learning model emphasize positive interdependence, individual accountability, and promotive interaction as essential for effective group work (Johnson and Johnson 1989). Beyond cognitive gains, collaboration supports communication, negotiation, and perspective-taking (Laal and Ghodsi 2012). In product design education, collaboration strengthens ideation, critique, and refinement, as ideas improve through collective iteration. In this study, collaborative learning extends beyond peer interaction to include engagement with digital tools, particularly generative AI which acts as a mediating artifact within a sociomaterial learning environment (O'Malley 1995). This reflects contemporary views of learning as distributed across people, tools, and representations rather than located solely in individual cognition.

Creativity

Creativity is increasingly understood as a socially embedded process rather than an isolated mental act (Csikszentmihalyi 1996). Csikszentmihalyi's Systems Model conceptualizes creativity as emerging from interactions among three elements: the person who generates ideas, the domain of symbolic knowledge, and the field that evaluates and legitimizes contributions (Csikszentmihalyi 1999). In this study, students act as the "person," generative AI as a tool for product design visualization represents the "domain," and the research team functions as the "field." Expanding this view, Glăveanu's Distributed Creativity positions creativity as enacted through human and material interactions (Glăveanu 2014; Glăveanu 2021). Generative AI operates as a creative tool that shapes ideation and influences output through co-construction. By integrating both perspectives, this study situates ideation as an emergent process involving learners, AI systems, design briefs, and evaluative practices rather than individual cognition alone.

Self-efficacy

Self-efficacy refers to individuals' beliefs in their ability to execute actions required to achieve specific outcomes (Bandura 1997). Within Bandura's Social Cognitive Theory, it influences motivation, persistence, and performance (Bandura 1986). Its development is shaped by mastery experiences, vicarious learning, social persuasion, and affective states (Bandura 1986). High self-efficacy supports resilience, risk-taking, and persistence in creative tasks (Pajares and Schunk 2002; Zimmerman 2000). In product design, students' belief in their creative capabilities affects their willingness to explore novel directions. Generative AI can strengthen self-efficacy by offering cognitive support, but may also create dependence or intimidation if perceived as superior (Tierney and Farmer 2002). Accordingly, this study positions self-efficacy as a mediating factor shaping how students engage with AI-supported ideation.

Methodology

This study is guided by a conceptual framework that integrates collaborative learning, creativity theory, and self-efficacy. Generative AI is positioned not as a technological resource but as a mediating tool and co-participant in problem-solving during the ideation

phase (Vygotsky 1978; Johnson and Johnson 1989). In line with systems-based models of creativity (Csikszentmihalyi 1999; Glăveanu 2014), creative outcomes are viewed as emerging from the interaction between learners, peers, and tools. Simultaneously, following the theory of self-efficacy, the framework assumes that the constructive engagement from using the generative AI shapes students' confidence and their creative capabilities (Bandura 1997).

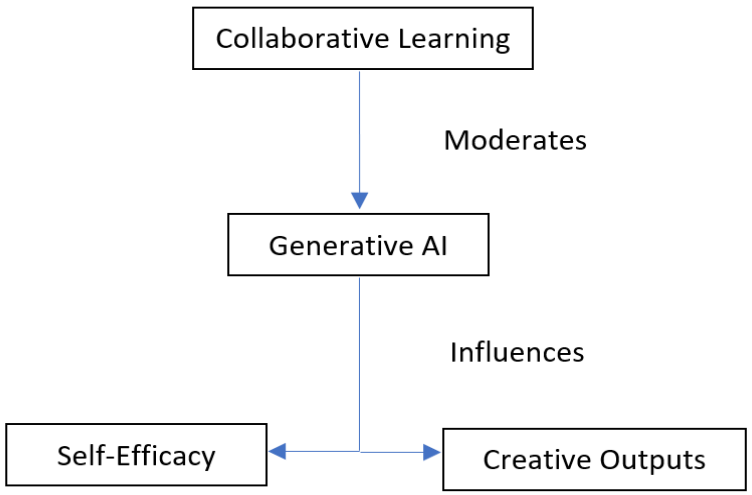


Figure 1. Conceptual Framework of AI-Supported Ideation in Product Design Education

Figure 1 illustrates the framework, which proposes that using generative AI during ideation can enhance creative output both directly and indirectly by strengthening students' self-efficacy. This process is further mediated by collaborative learning, where peers work collectively and interact with AI as a co-creative partner. A controlled experiment was conducted with fifty purposively selected product design students (Guest, Bunce, and Johnson 2006) from the Faculty of Applied and Creative Arts, Universiti Malaysia Sarawak, organised into five groups. Although product design education normally involves four phases (empathy, define, ideation, prototyping/testing), this study focused exclusively on ideation, as it is the stage where the generation of diverse possibilities is most critical. Generative AI is especially impactful here due to its capacity to generate rapid visual variations. The ideation process

was operationalised across three structured phases, allowing for a focused examination of how AI influences creativity, collaboration, and self-efficacy during concept development. The study was not intended to replicate the full design cycle but to isolate AI's role within ideation. The "controlled" element was ensured by providing all groups with the same design brief, equal time allocation, standardised instructions, and a consistent environment to minimise external variables.

Phase 1: demonstration and brainstorming session

Phase 1 began with a 20-minute session designed to prepare respondents for the next stage. The research team demonstrated how to construct prompts and use ChatGPT 4.0 to generate visual outputs. Each group was given two reference sketches—a computer mouse and a bread toaster (see Table 1), and asked to analyse them to identify design features with potential for innovation.

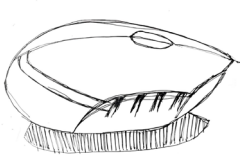
	
(a)	(b)

Table 1. Reference image (a) Computer mouse; (b) Bread toaster

Working collaboratively, groups developed prompts using three key elements: (1) the product subject, (2) intended innovative features, and (3) preferred style. For example, they described the base product (e.g., bread toaster in a kitchen cabinet), specified enhancements (e.g., touch controls with menu options), and added stylistic direction (e.g., futuristic appearance with hyper-realistic imagery). To maintain consistency, all prompts followed a standard structure, beginning with "Based on the given image…" and ending with "… hyper realistic photography." This approach allowed flexibility in interpretation while keeping the generated visuals focused and comparable across groups.

Phase 2: generating images

Phase 2 involved applying the prompts developed earlier to produce visual concept images using ChatGPT 4.0 (https://chatgpt.com/). Over a 30-minute session, students uploaded the reference sketches (computer mouse and bread toaster) and used structured prompts describing the subject, features, and style. The AI generated corresponding visuals. To reflect iterative design practice, each group of ten students was allowed up to ten prompt revisions to refine their results. All final prompts and selected images were recorded.

Visual Dimensions of Images		
Visual Value	Visual Performance	Image's Visually Dimension
A dimension reffered to the non-discursive characteristics of images which allows a simultaneous per ception of visual information	A dimension that indicates the ways visual signs are composed in an image or to what it is visually represented.	A dimension where the visual become an element of persuasiveness. It underlines both the importance of visual information in communication and the rhetorical power of images.
Purpose: to assess how well AI-generated features matched the intended design ideas.	Purpose: to evaluated how clearly and effectively the prompts shaped the image outcomes.	Purpose: to determine the overall image quality such as balance, harmony, and how closely it resembled the reference sketch.

Table 2. Visual dimension of images, adapted from Burri (2012)

In this study, image analysis referred to Mason and Burri's methods (Mason 2005; Burri 2012). Mason emphasized descriptive observation and organizing image plates linked to theory, while Burri identified three visual dimensions: (1) visual value, indicating immediate perceptual qualities; (2) visual performance, referring to how elements are structured; and (3) visual dimension, relating to emotional resonance or persuasive impact. These were consolidated into one framework (see Table 2). Visual value assessed how closely AI-generated elements aligned with intended concepts, visual performance examined the clarity and influence of prompts on outcomes, and the visual dimension evaluated image quality in terms of harmony, balance, and resemblance to the reference sketches.

Phase 3: debrief interview session

Phase 3 involved 20-minute debrief interviews to capture respondents' reflections on Phases 1 and 2. For Phase 1, the questions addressed: (1) their experience during the briefing, (2) clarity of instructions and demonstrations, and (3) the process of identifying design criteria. For Phase 2, the discussion focused on: (1) group confidence and teamwork in generating prompts, (2) experiences using ChatGPT 4.0 and refining outputs, and (3) perceptions of creativity and innovation in the AI-generated images.

ID	Respondent 1	Respondent 2	Respondent 3
Protocol Time	05:18	03:41	07:25
Transcriptions	"The briefing was very thorough. The instructions on how to generate and use prompts were clear, and the examples really helped me understand the process."	"I appreciated the detailed document provided. The step-by-step guidance on using ChatGPT 4.0 was especially helpful."	"I found the session quite informative. It was my first time working with generative AI. and the demonstrations made it much easier to grasp."
Attributes	• Briefing was very thorough. • Instructions were clear. • The examples are good.	• The document is detail. • The guidance of using ChatGPT 4.0 is effective.	• The briefing was informative. • The demonstration is effective.
Open Codes: Categories of information	Respondent had a thorough briefing, clear instructions, and good examples during the briefing session.	Respondent bad a good guidance on ChatGPT 4.0 with detailed document.	The briefing and demonstrations help the respondent.
Axial Codes	Respondents' experience during the briefing session is considered good due to a thorough briefing, clear instructions, and good examples during the briefing session.	Respondents' experience during the briefing session is considered good due to a good guidance on ChatGPT 4.0 with detailed document.	Respondents' experience during the briefing session is considered good due to the effectiveness of briefing content and demonstrations.
Selective Codes	Respondents' experiences during 1he briefing session were considered positive due to be thoroughness of the briefing, the clarity of instructions, the quality of examples provided, the detailed guidance on using ChatGPT 4.0, and the overall effectiveness of the briefing content and demonstrations.		

Table 3. Sample of coding on three respondents' experiences during the debrief interview session

Table 3 (prev. page) illustrate the sample of coding on three respondents' experiences during the debrief interview session. The interview data were analyzed using a three-step coding process: open coding, axial coding, and selective coding (Creswell 2009; Saldaña 2015). This method helps organize qualitative data into meaningful categories. In open coding (see Table 3), key parts of respondents' responses were labeled and broken into smaller pieces. During axial coding, these labels were grouped into broader categories by identifying connections between them. Some codes were reorganized or refined to better fit emerging ideas. In the final step, selective coding, the researcher identified the most important themes by looking at how the categories were related. This step was sometimes repeated to adjust previous codes when new insights appeared. This stage also involves deciding which themes are most relevant to the research goals (Muller and Kogan 2012). By the end of the process, only the key themes were kept, giving a clear summary of respondents' experiences and feedback.

Data findings and discussions

The AI-generated visuals in Table 4 and 5 reflected how well each group collaborated in crafting prompts. Groups 1 and 4 consistently produced coherent outcomes, such as Bauhaus and Japanese minimalist toaster concepts and computer mouse designs incorporating ergonomic curves, lighting effects, or superhero-inspired colour schemes. Their success aligns with Johnson and Johnson's cooperative learning model, as shared regulation and collective refinement led to clearer AI instructions (Johnson and Johnson 1989). Conversely, Groups 2 and 3 frequently omitted essential features such as safety elements, colour variation, large bread capacity, or themed illumination, highlighting that AI creativity depends on iterative prompting rather than automation. This supports Glăveanu's view of distributed creativity emerging through human–technology interaction (Glăveanu 2014; Glăveanu 2021). Overall, this study examines how design prompts (particularly the subject, function, and style) shaped AI-generated outputs, underscoring the need for clear and imaginative prompt construction. Emphasis on innovative features allowed the analysis of how well AI translated functional and conceptual intent. The findings reveal both the potential and limits of AI in stimulating creativity,

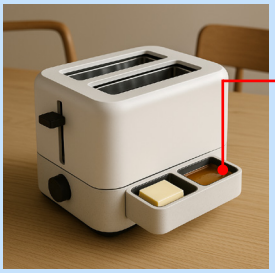
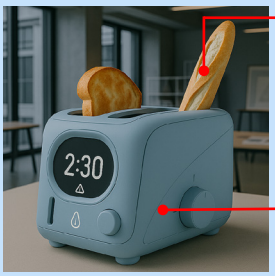
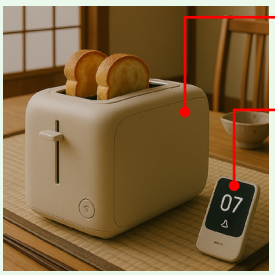
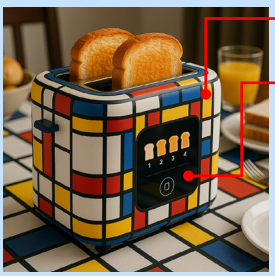
Input Prompt	Prompt Synthesis	Generated AI Image	Descriptive Analysis of Generated Image
Group 1: Based on the given image, generate an image of bread toaster at a dining area. The bread toaster has a compartment for honey jam and butter. In the style of Bauhaus and hyper realistic photography	• Subject: bread toaster at a dining area • Description: compartment for honey jam and butter • Style / Aesthetic: Bauhaus and hyper realistic photography		• Bread toaster at a dining area was generated • Compartment for honey jam and butter was successfully included. • The Bauhaus style was successfully captured the element of minimalism.
Group 2: Based on the given image, generate an image of bread toaster on a dining table at luxury restaurant. The bread toaster has a futuristic timer, temperature adjuster, and safety elements from excessive heat. In the style of Zaha Hadid and hyper realistic photography	• Subject: bread toaster on a dining table at luxury restaurant • Description: futuristic timer, temperature adjuster, and safety elements from excessive heat • Style / Aesthetic: Zaha Hadid and hyper realistic photography		• Bread toaster on a dining table at luxury restaurant was generated. • The futuristic timer and temperature adjuster were generated. The safety elements from excessive heat were poorly implemented on the styling form. • The styling form successfully imitates Zaha Hadid's influence.
Group 3: Based on the given image, generate an image of bread toaster on design studio pantry. The bread toaster has a space for multiple type of breads such sourdough and baguette, safety timer controller and touch screen. In the style of futuristic and hyper realistic photography	• Subject: bread toaster on design studio pantry • Description: space for multiple type of breads such sourdough and baguette, safety timer controller and touch screen • Style / Aesthetic: futuristic and hyper realistic photography		• The space for multiple type of breads such sourdough and baguette were poorly generated. • The safety timer controller and touch screen were successfully generated. • Bread toaster on design studio pantry was generated. • The futuristic styling form was successfully generated with light blue color.
Group 4: Based on the given image, generate an image of bread toaster on Japanese inspired dining table. The bread toaster has a wireless timer controller and remote-control screen. In the style of Japanese and hyper realistic photography	• Subject: bread toaster on Japanese inspired dining table • Description: wireless timer controller and remote-control screen • Style / Aesthetic: Japanese and hyper realistic photography		• Bread toaster on Japanese inspired dining table was generated. • Wireless timer controller and remote-control screen were generated. • The Japanese style was successfully generated with the element of simplicity.
Group 5: Based on the given image, generate an image of bread toaster on contemporary dining table. The bread toaster has a touch control with bread toast menu options. In the style of de Stijl and hyper realistic photography	• Subject: bread toaster on contemporary dining table • Description: touch control with bread toast menu options • Style / Aesthetic: de Stijl and hyper realistic photography		• Bread toaster on contemporary dining table were generated. • Touch control with bread toast menu options were generated. • The de Stijl style was successfully generated with the iconic color palette

Table 4. Findings of image-based analysis (bread toaster) from the outcomes of Phase 2

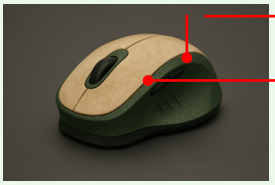
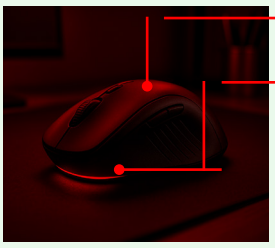
Input Prompt	Prompt Synthesis	Generated AI Image	Descriptive Analysis of Generated Image
Group 1: Based on the given image, generate an image of computer mouse on the office table. The computer mouse has a features of ergonomic handl ng and sensor colour variations. In the style of superheroes and hyper realistic photography	• Subject: computer mouse on the office table • Description: ergonomic handling and sensor colour variations • Style / Aesthetic: superheroes and hyper realistic photography		• Computer mouse on the office table was generated • The features of ergonomic handling and sensor colour variations was successfully included. • Superheroes style was successfully captured using the iconic Superman's blue and red colors.
Group 2: Based on the given image, generate an image of computer mouse on the gaming table. The computer mouse has a features of wireless technology, ergonomic handling, and form inspired from Renaissance art. In the style of minimalist and hyper realistic photography	• Subject: computer mouse on the gaming table • Description: wireless technology, ergonomic handling, sensor colour variations, and form inspired from Renaissance art • Style / Aesthetic: minimalist and hyper realistic photography		• Computer mouse was generated but not on the gaming table • Wireless technology and ergonomic handling was generated but the sensor colour variations was not generated and a form inspired from Renaissance art were poorly implemented. • The overall image illustrate the element of minimalist
Group 3: Based on the given image, generate an image of computer mouse on the Chinese inspired table. The computer mouse has a features of ergonomic handling, wireless, Chinese pattern and disco colour lighting. In the style of Art Nouveau and hyper realistic photography	• Subject: computer mouse on the Chinese inspired table • Description: ergonomic handling, wireless, Chinese pattern , and disco colour lighting • Style / Aesthetic: Art Nouveau and hyper realistic photography		• Computer mouse on the Chinese inspired table was generated. • Ergonomic handling, wireless, Chinese pattern were generated but not the disco colour lighting • The element of Art Nouveau was successfully generated.
Group 4: Based on the given image, generate an image of computer mouse on the table in design studio. The computer mouse has a features of sensor with menacing lighting colour, wireless technology, and ergonomic handling. In the style of menacing red and hyper realistic photography	• Subject: computer mouse on the table in design studio • Description: sensor with menacing lighting colour, wireless technology, and ergonomic handling • Style / Aesthetic: menacing red and hyper realistic photography		• Computer mouse on the table in design studio was generated. • Sensor with menacing lighting colour, wireless technology, and ergonomic handling were generated. • Menacing red as an environment was succesfully generated
Group 5: Based on the given image, generate an image of computer mouse on the gaming table. The computer mouse has a features of wireless technology, ergonomic design, futuristic colours lighting. In the style of Japanese Samurai and hyper realistic photography	• Subject: computer mouse on the gaming table • Description: wireless technology, ergonomic design, futuristic colours lighting • Style / Aesthetic: Japanese Samurai and hyper realistic photography		• Computer mouse on the gaming table were generated. • Wireless technology, ergonomic design, futuristic colours lighting were generated. • The element of Japanese Samurai was successfully generated but not literally.

Table 5. Findings of image-based analysis (computer mouse) from the outcomes of Phase 2

encouraging experimentation, and fostering collaborative self-efficacy. Through AI-supported collaboration, students explored ideas more freely and gained deeper insight into product innovation and customization. AI acted not as a substitute for creativity but as a mediating tool that enhanced ideation through co-construction and iterative collaboration.

Table 6 summarize thematic coding matrix linking participant quotes to theoretical constructs from the debrief interview. Re-

Transcriptions	Open Codes (Initial Concept Label)	Axial Coding (Grouped Category)	Selective Coding (Core Theoretical Construct)
"The briefing session helped reduce my anxiety because everything was explained step-by-step in a very friendly manner."	Felt reassured.	Positive emotional response to instruction.	Self-efficacy development (Bandura 1986)
"Watching the live demonstration made it much easier to understand compared to only looking at written instructions."	Preferred demonstration-based learning	Visual & experiential scaffolding	Instructional clarity / Cognitive readiness
"Identifying the design criteria before writing prompts forced me to think more carefully about function, material, and style."	Structured thinking before prompting	Metacognitive planning	Creative problem framing (Creativity process)
"Working in pairs to write prompts helped me gain confidence because we could build on each other's ideas instead of thinking alone."	Mutual idea exchange	Collaborative negotiation	Cooperative learning (Johnson & Johnson 1989)
"Refining the prompt felt like solving a puzzle because every small change produced a different AI output."	Iterative experimentation	Trial-and-error refinement	Mastery through iteration (Self-efficacy spiral)
"The Al sometimes added details I did not expect, but those surprises actually made the design more innovative than I originally imagined."	Al as co-creator	Human-AI interaction expands ideas	Distributed creativity (Glăveanu 2014, 2021)

Table 6. The Summary of Debrief Interview: Thematic Coding Matrix Linking Participant Quotes to Theoretical Constructs

spondents reported highly positive experiences during the initial briefing session. Several respondents explained that "the briefing session helped reduce my anxiety because everything was explained step-by-step in a very friendly manner." This sense of reassurance created an early foundation of confidence, allowing respondents to engage with the AI tools without hesitation. Clarity of instruction played a major role in this effect. As one participant stated, "watching the live demonstration made it much easier to understand compared to only looking at written instructions," indicating that visual scaffolding supported comprehension more effectively than text-based guidance alone. When asked about identifying design criteria prior to writing prompts, many respondents acknowledged that the process deepened their analytical thinking. One reflected that "identifying the design criteria before writing prompts forced me to think more carefully about function, material, and style," suggesting that structured reflection led to more intentional design articulation. Collaboration also emerged as a critical factor in building confidence. As one respondent shared, "working in pairs to write prompts helped me gain confidence because we could build on each other's ideas instead of thinking alone." Respondent described their experience using ChatGPT 4.0 as iterative and exploratory. Rather than expecting perfect outputs on the first attempt, most adopted a problem-solving mindset. One participant explained that "refining the prompt felt like solving a puzzle because every small change produced a different AI output." This trial-and-error process positioned AI as a responsive collaborator rather than a passive generator. Finally, respondents consistently acknowledged the AI's capacity to extend their creativity. As one noted, "the AI sometimes added details I did not expect, but those surprises actually made the design more innovative than I originally imagined." The findings reveal that the structured briefing session and live demonstrations were pivotal in reducing anxiety, establishing early confidence and enabling students to engage with AI tools without hesitation. Clear visual guidance proved more effective than written instructions alone, supporting better comprehension and task readiness. Identifying design criteria before prompt creation encouraged deeper analytical thinking, prompting students to consider function, material, and style more intentionally. Collaboration further strengthened confidence, as working in

pairs enabled idea sharing and reduced individual pressure. Participants also described their interaction ChatGPT 4.0 as an iterative, exploratory process, where refining prompts was viewed as problem-solving rather than trial-and-error. This positioned AI as an active co-creator rather than a passive tool. Importantly, respondents acknowledged that AI-generated outputs often introduced unexpected but valuable creative possibilities, enhancing innovation beyond their initial ideas.

Conclusion

This study explored the integration of generative AI in the ideation phase of product design education, focusing on its impact on creativity, self-efficacy, and collaborative learning. The findings show that AI supports rather than replaces human creativity, acting as a co-creative partner that helps students convert abstract ideas into rapid visual outputs. This demonstrates AI's value in translating imagination into tangible concepts. A key insight was the importance of structured onboarding. Demonstrations and guided briefing sessions equipped students with foundational skills, increasing confidence and readiness to experiment. Early scaffolding contributed to effective engagement, consistent with guided learning principles. The iterative nature of prompt development also revealed initial challenges in articulating ideas verbally. However, through collaboration and refinement, students improved their prompt engineering abilities and became more aware of how linguistic precision shapes visual results. The image-based outputs further showed that students were not passive users. They critically evaluated aesthetic, functional, and persuasive aspects of the visuals, using AI-generated images as stimuli for further ideation rather than as final solutions. This reflects design thinking practices and supports theories of co-construction and visual reasoning. Overall, the study demonstrates that generative AI can enhance ideation by amplifying creativity, building self-efficacy, and reinforcing collaborative engagement. It offers practical direction for educators seeking AI-augmented pedagogical strategies and lays groundwork for future research into implementation, ethics, platform comparison, and long-term creative development.

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Artificial Intelligence (AI)-Aided Collaborative Design in Industrial Design Education for Final Year Projects (FYP)

Improving Workflow and Innovation

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Abstract

The integration of Artificial Intelligence (AI) into design education is transforming collaborative learning and creative practice, particularly in Industrial Design. A theoretical framework was developed through the literature review to guide this study, which investigates how AI-assisted tools influence creativity, collaboration, and workflow efficiency in Final Year Projects (FYPs) among 38 Industrial Design students at a Malaysian university. Employing a mixed-methods design, two classes participated in a quasi-experimental comparison: one integrated AI tools throughout the design process, while the other used traditional methods. Students applied AI tools across five project phases: research (Notion AI, Elicit), ideation (DALL·E, MidJourney), design simulation (Fusion 360 AI, Rhino AI), reporting (ChatGPT, Grammarly), and prototyping (generative design tools). Quantitative data from project rubric scores and supervisor evaluations were complemented by qualitative insights from reflective journals and focus group discussions. Results showed that the AI-assisted class achieved higher creativity and design quality, supported by enhanced efficiency and faster iteration. However, students also reported challenges related to over-reliance on AI, ethical concerns about authorship, and reduced hands-on engagement. The study concludes that AI can serve as a valuable cognitive and creative partner in design education when integrated within a reflective and human-centered pedagogical framework that maintains critical thinking, originality, and ethical responsibility.

Keywords: AI-Aided Design, Collaborative Design, Industrial Design education, Final Year Project (FYP), Human-AI Collaboration, Human-Centered Design

Introduction

The integration of Artificial Intelligence (AI) in higher education, particularly within creative and design-oriented disciplines, is transforming both pedagogical strategies and design practices (Al-Zahrani and Alasmari 2024). Industrial Design education is distinct from many other programs due to its reliance on studio-based learning, project-driven collaboration, and iterative prototyping (Oxman 2006). Students must balance aesthetic, functional, and human-centered considerations, translating abstract ideas into tangible outcomes. This combination of creative reasoning and technical execution positions Industrial Design as a discipline that can both benefit from and critically interrogate AI integration.

Collaborative projects, particularly Final Year Projects (FYPs), are central to preparing students for real-world design challenges (Deighton et al. 2024). These projects require multidisciplinary coordination, iterative development, and conceptual innovation, often under tight time and resource constraints. Traditional collaborative workflows can be inconsistent, relying heavily on communication and the individual skills of group members, which may affect project outcomes and learning experiences.

In this study, the FYP were developed under the theme "AI-Aided Design for Inclusivity." The theme emphasized using AI to support inclusive apnd accessible design by gathering and analyzing diverse user data to inform design decisions. Students applied AI tools to propose solutions that address varying user abilities and backgrounds while considering sustainable materials and eco-friendly production methods. This approach encouraged the integration of technology, empathy, and sustainability within the collaborative design process.

AI tools offer potential to augment multiple stages of the design process, including automating repetitive tasks, generating concept visuals, and supporting generative modeling (Lorenc-Kukuła 2025). Platforms such as ChatGPT, DALL·E, and AI-assisted CAD tools are increasingly explored by students to support ideation, visualization, and collaborative problem-solving. The selection of these tools in this study was guided by their alignment with the learning objectives of Industrial Design education, their accessibility to students, and their demonstrated utility in supporting creative workflows (Zhou and Peng, 2025; Melker et al. 2025).

The integration of AI in collaborative learning environments also carries discipline-specific risks. Overreliance on AI-generated outputs may reduce critical thinking, originality, and hands-on craftsmanship. Ethical concerns—such as authorship attribution, data bias, and the diminishing of material engagement—are particularly salient in a field rooted in human creativity and tactile problem-solving. These factors highlight the need for structured pedagogical frameworks that integrate AI in ways that support reflective thinking, iterative design, and equitable collaboration (Parveen et al. 2024).

This study therefore investigates how structured AI use can enhance collaborative workflows and innovation in final-year Industrial Design projects. By focusing on the Malaysian higher education context—where AI adoption in design curricula remains emerging—this research examines both the pedagogical opportunities and challenges of embedding AI into collaborative design learning. The primary objective is to explore the impact of AI-assisted tools on students' collaborative design processes, with particular emphasis on workflow efficiency, creativity, and innovation. The central research question guiding this study is: How does the integration of AI tools affect collaborative workflows and innovation processes in final-year Industrial Design projects?

By addressing this question, the study contributes to the growing discourse on AI in education, offering discipline-specific insights into collaborative learning with AI, informing curriculum design, and proposing strategies to balance AI support with critical engagement, creativity, and reflective practice in Industrial Design education.

Literature Review and Theoretical Framework

The increasing incorporation of Artificial Intelligence (AI) in design education has introduced new dynamics in creativity, collaboration, and user-centered innovation. In the context of Industrial Design, AI technologies are progressively reshaping how students conceptualize, prototype, and evaluate their design outputs (Zhou and Peng 2025; Melker et al. 2025). However, to effectively guide this integration, a robust theoretical framework is necessary to ensure that AI use remains grounded in human values, empathy, and

iterative learning. To this end, this study is underpinned by Norman's Human-Centered Design (HCD) framework (Norman 2013).

According to Norman (2013), the HCD framework emphasizes designing with a deep understanding of users' needs, abilities, limitations, and contexts of use. The approach promotes a cyclical, iterative process involving observation, ideation, prototyping, and testing, where user feedback and contextual awareness drive design improvement. Within this paradigm, technology serves as an enabler, not a replacement for human creativity or judgment. Applied to Industrial Design education, the HCD framework underscores the importance of empathy, reflection, and collaborative problem-solving—skills that are essential for inclusive and socially responsible design practices (Oxman 2006; Deighton et al. 2024).

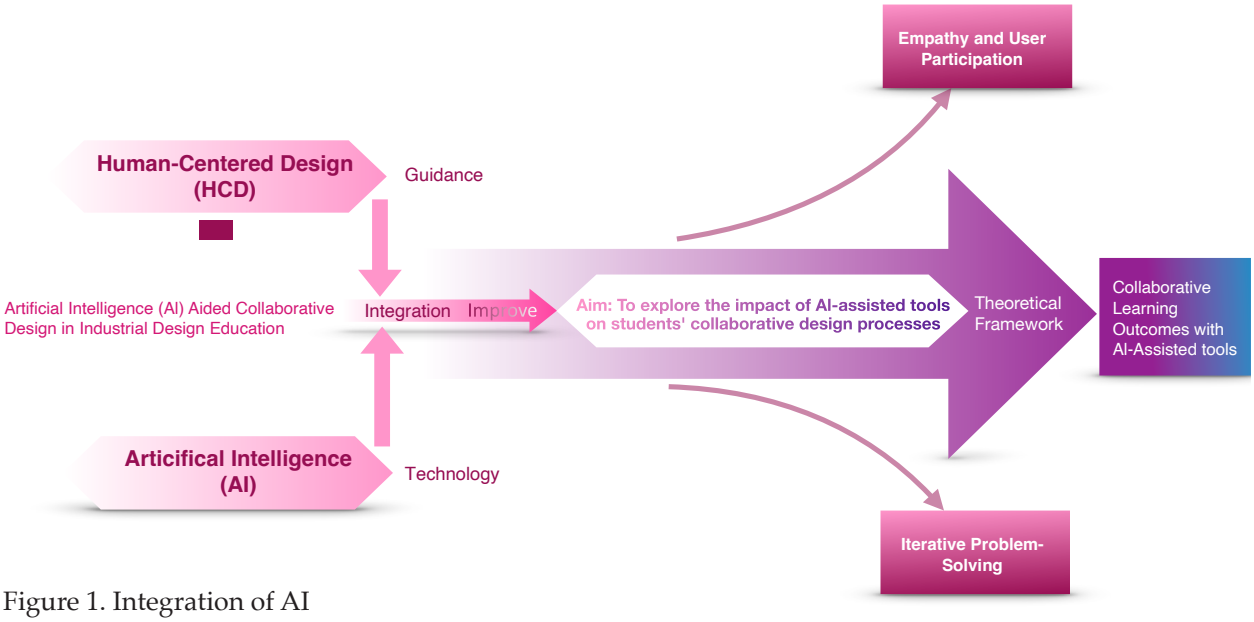

Figure 1. Integration of AI Tools within Norman's Human-Centered Design Framework for Collaborative Industrial Design Education

Figure 1 illustrated the theoretical framework on Integration of AI Tools within Norman's Human-Centered Design Framework for Collaborative Industrial Design Education. By integrating Norman's HCD framework, this study situates AI not merely as a productivity enhancer but as a supportive element within human-centered learning and design processes, HCD provides pedagogical guidance, while AI offers technological support in Industrial Design education, with the aim of exploring the impact of AI-assisted

tools on students' collaborative design process. This theoretical lens enables the analysis to explore how AI-assisted tools can enhance inclusivity, creativity, and decision-making within Final Year Projects (FYPs). The application of HCD thus ensures that technological advancements remain aligned with pedagogical and ethical imperatives that prioritize human creativity, empathy, and reflective practice.

Methodology

Research Design

This study employed a mixed-methods research design, which was appropriate for examining both the measurable and experiential dimensions of AI integration in Industrial Design education (Creswell 2014). As illustrated in Figure 2, the research was conducted in two

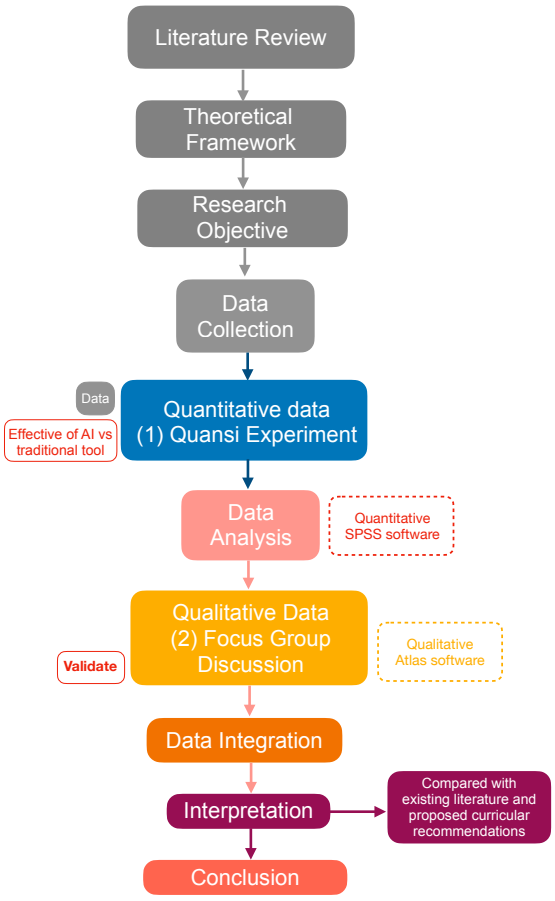

Figure 2. Flow of research design

phases. The first phase involved a quantitative quasi-experimental design, focusing on evaluating project outcomes to determine the effects of AI-assisted tools on students' collaborative workflows. Project performance was assessed through formal rubric evaluations based on criteria such as design quality, creativity, efficiency, and the extent to which AI contributed to the overall process.

Following the quantitative phase, a qualitative inquiry was undertaken to explain and expand upon the statistical findings. This phase explored students' perceptions, challenges, and experiences with AI tools through reflective journals and focus group discussions, complemented by faculty observations. The qualitative insights provided a deeper understanding of how AI influenced collaboration, ideation, and innovation during the Final Year Projects (FYPs) (Sobaih et al. 2025). The sequential integration of quantitative and qualitative data allowed for a comprehensive interpretation of the pedagogical implications of AI-aided collaborative design, offering both empirical evidence and contextual understanding of its impact on Industrial Design education.

Participants and Context

This study was conducted at a Malaysian public university that has recently introduced emerging technologies, including Artificial Intelligence (AI), into its Industrial Design curriculum. The participants comprised 38 final-year Industrial Design students (mean age = 23.1 years) enrolled in a mandatory capstone course that forms the culmination of their academic program. These students undertook a semester-long Final Year Project (FYP) under the theme "AI-Aided Design for Inclusivity," which encouraged the use of technology to support human-centered, creative, and sustainable design practices.

For the quantitative phase, the students were organized into two classes, each consisting of 19 students. One class functioned as the AI-assisted group, integrating selected AI tools throughout the research, ideation, development, and reporting stages of their projects. The other class served as the traditional group, completing their projects using conventional design methods without AI assistance. This quasi-experimental design enabled a comparative analysis of how AI integration influenced workflow efficiency, creativity, and collaboration in the design process.

In the qualitative phase, both classes participated in focus group discussions and maintained reflective journals to provide deeper insight into their learning experiences. These qualitative data helped explain and contextualize the quantitative findings, revealing how students perceived the benefits and challenges of AI integration within collaborative design projects. Together, the two phases provided a comprehensive understanding of how AI-assisted tools impact creativity, teamwork, and innovation in Industrial Design education.

Instruments and Tools

To assess the impact of AI tools on the collaborative design process in final-year Industrial Design projects, this study employed a combination of AI tools across five key project stages and a set of data collection instruments. These tools and instruments were integral in evaluating the efficiency, creativity, and effectiveness of AI in enhancing the students' workflows. These tools were strategically integrated into the following project phases as listed in Table 1.

Project Phase	AI Tools Used	Purpose
Research & Ideation	Notion AI, Elicit, DALL·E, Mid Journey	Organizing literature, generating questions, and visual mood boards
Design Development	Fusion 360 AI, Rhino AI	Generative modelling, structure simulation
Writing & Documentation	ChatGPT, Grammarly	Report drafting, grammar, and language improvement
Prototyping	Autodesk Generative Design, Dream Fusion	Form optimization and AI-assisted fabrication

Table 1. AI Tools Used in Each Project Phase

Throughout the project, AI tools were strategically integrated across phases to improve efficiency and foster creativity, as Figure 3 illustrates the design process. In the Research & Ideation phase, Notion AI and Elicit supported literature synthesis and research question development, while DALL·E and Mid Journey generated visual mood boards and concept imagery to inspire design exploration. During Design Development, Fusion 360 AI and Rhino AI enabled

generative modelling, structural simulation, and design optimization, assisting students in visualizing complex forms and assessing feasibility. In the Writing & Documentation phase, ChatGPT facilitated report drafting and refinement, while Grammarly ensured linguistic accuracy and professional tone (Zhu et al., 2024). In the Prototyping phase, Autodesk Generative Design and Dream Fusion aided in form optimization and AI-assisted fabrication, streamlining the transition from digital models to 3D-printed prototypes. Collectively, these tools enhanced the design workflow from initial concept to final output (Ma et al. 2023).

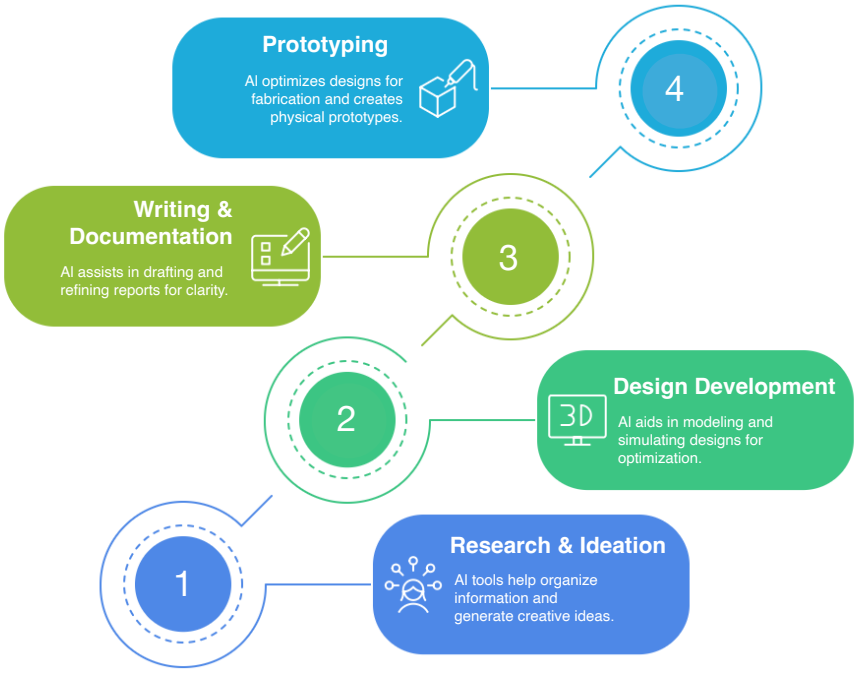

Figure 3. AI-Aided design process

Data Collection

Data were collected in two sequential phases—quantitative followed by qualitative—to provide both measurable and experiential insights into the impact of AI tools on the collaborative design process. The overall data collection process is illustrated in Figure 4 (next page).

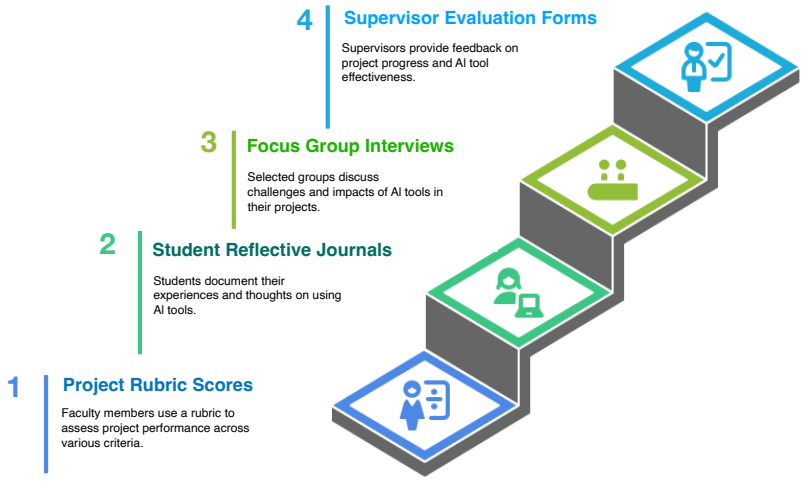

Figure 4. Data collection process for evaluating AI tools in the collaborative design process

In the quantitative phase, data were obtained through Project Rubric Scores, which provided an objective measure of each class's project performance. Faculty evaluators assessed both the AI-assisted and traditional classes using a standardized rubric based on five key criteria: design quality, creativity, functionality, collaboration, and technical execution, rated on a 0–100 scale (Costa 2024). This quantitative data enabled direct comparison of the two instructional conditions and allowed the study to evaluate the measurable influence of AI tools on design outcomes. Supervisor Evaluation Forms were also used to capture instructors' observations on project progress, teamwork dynamics, and the practical effectiveness of AI tools in facilitating design workflows.

In the qualitative phase, data were gathered to explain and expand upon the quantitative results. Students from both classes participated in Structured Reflective Journals, submitted weekly throughout the semester. These journals, following guided prompts, invited students to describe their experiences with collaboration, the perceived role of AI in creativity and problem-solving, and challenges encountered during the design process (Sudirman et al. 2024; Schimpf et al. 2024). The structured format ensured consistency and facilitated thematic comparison across participants.

To complement the journals, Focus Group Interviews were conducted with selected representatives from both the AI-assisted and traditional classes. These sessions were specifically designed to capture the social and collaborative dynamics of AI tool use—how students debated ideas, negotiated shared understandings, and collectively critiqued AI-generated outputs within their teams. The interviews explored students' perceptions of AI integration, its influence on teamwork and creativity, and the balance between technological support and human decision-making. The interview guide was adapted from Tripathi and Smriti (2025), who examined students' experiences with AI in higher education, and was reviewed by two design education experts to ensure contextual relevance and clarity.

Together, these quantitative and qualitative instruments provided a comprehensive dataset for triangulation, allowing the study to analyze pnot only the measurable differences between AI-assisted and traditional design processes but also the underlying perceptions, behaviors, and collaborative experiences that shaped those outcomes.

Data Analysis

The data collected from both quantitative and qualitative instruments were analyzed sequentially to provide a comprehensive understanding of the impact of AI tools on collaborative design processes in Industrial Design education. Consistent with the sequential explanatory mixed-methods design, the quantitative analysis was conducted first to identify measurable differences between the AI-assisted and traditional classes, followed by qualitative analysis to explain and contextualize those findings.

In the quantitative phase, data from the Project Rubric Scores and Supervisor Evaluation Forms were analyzed to assess project outcomes across five dimensions: design quality, creativity, functionality, collaboration, and technical execution. Each criterion was evaluated on a scale from 0 to 100, with higher scores indicating better performance. Descriptive statistics—including mean, median, and standard deviation—were computed to summarize the data and identify overall trends. The mean rubric score for the AI-assisted class was 85.4, while the traditional class scored 78.3, indicating higher overall performance among students who used AI tools. The

standard deviation for the AI-assisted class (5.2) was lower than that of the traditional class (7.4), suggesting more consistent results among AI users.

An independent samples t-test was then applied to determine whether these differences were statistically significant. Results showed that the AI-assisted class performed significantly better in design quality and creativity ($p = 0.03$), while no significant differences were observed in functionality and technical execution ($p = 0.18$). These findings indicate that AI tools had a more substantial impact on the creative and innovative dimensions of design learning, whereas technical outcomes remained comparable between the two instructional approaches.

In the qualitative phase, data from Student Reflective Journals and Focus Group Discussions were analyzed using the six-phase reflexive thematic analysis process described by Naeem et al. (2023). This process involved familiarization with the data, generating initial codes, developing and refining themes, and defining their meanings to ensure analytical rigor and transparency. The qualitative analysis provided deeper insight into how students experienced and perceived the integration of AI tools during their Final Year Projects. Four major themes emerged from the analysis—efficiency, creativity, tool limitations, and ethical concerns—which helped explain the quantitative results and illustrated the broader pedagogical and experiential impact of AI-assisted learning.

Finally, findings from both phases were integrated to develop a holistic interpretation of AI's influence on design education. Quantitative results demonstrated measurable improvements in creative performance, while qualitative insights revealed how AI tools shaped students' collaborative behaviors, reflective practices, and ethical considerations. This integrated interpretation strengthened the overall validity of the study by connecting objective outcomes with subjective experiences.

Results and Discussion

This section presents the findings from both the quantitative and qualitative phases of the study, highlighting the impact of Artificial Intelligence (AI) tools on collaboration, creativity, and efficiency in Industrial Design Final Year Projects (FYPs). Consistent with the sequential explanatory mixed-methods design, the **quantitative re-**

sults are presented first, followed by **qualitative insights** that explain and expand on these findings.

Quantitative Results

The analysis of **Project Rubric Scores** revealed that the **AI-assisted class** achieved higher overall performance than the **traditional class** across most assessment criteria. The mean rubric score for the AI-assisted class was **85.4**, compared to **78.3** for the traditional class. An independent samples t-test confirmed that these differences were statistically significant in **design quality and creativity** ($p = 0.03$), but not in **functionality** or **technical execution** ($p = 0.18$). This indicates that while AI integration enhanced creative ideation and workflow efficiency, it did not necessarily improve technical or engineering precision.

Supervisor evaluations supported these findings, noting that AI-assisted students demonstrated greater fluency in idea development and faster iteration cycles, particularly during the ideation and prototyping stages. However, supervisors also observed that some students displayed **over-reliance on AI outputs**, occasionally neglecting the refinement and manual problem-solving typically expected in design studio practice.

Qualitative Findings

The **qualitative phase**—drawing from student reflective journals and focus group discussions—offered deeper insights into how students experienced and interpreted AI use in their projects. Thematic analysis (Naeem et al. 2023) identified **four recurring themes**: **efficiency, creativity, tool limitations,** and **ethical concerns** (see Figure 5, next page).

Students in the AI-assisted class consistently reported increased **efficiency**, emphasizing that AI tools such as *Notion AI*and *Elicit* helped streamline literature review, organize design data, and generate early research insights. Many noted that these tools "saved time" and "reduced repetitive tasks," allowing more focus on ideation and design refinement. However, a few students acknowledged a tendency to rely too heavily on AI-generated content, which sometimes limited their own analytical depth and critical engagement.

The theme of **creativity** reflected both positive and cautious perspectives. Students widely agreed that tools such as *DALL·E* and

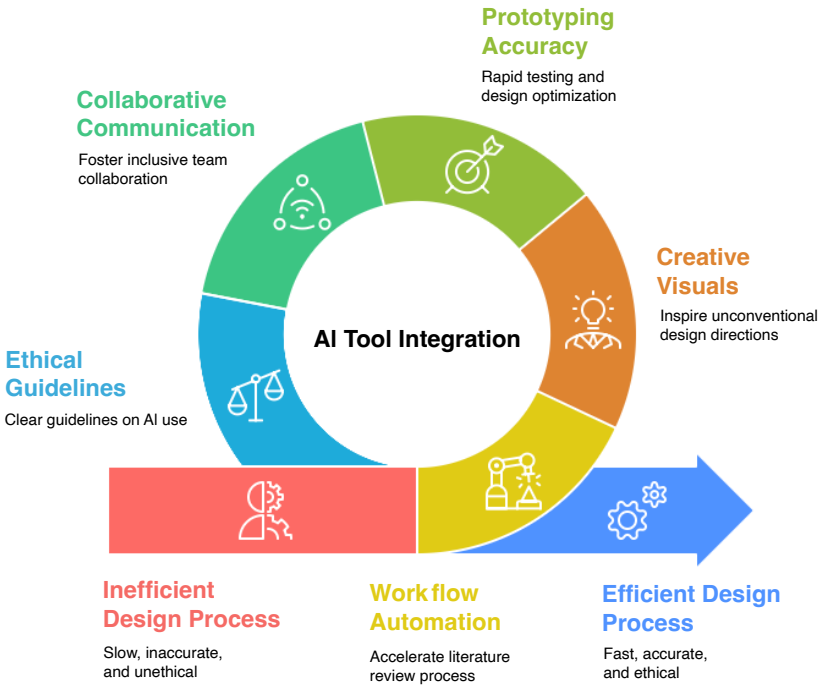

Figure 5. Recurring patterns and themes of AI in design education

MidJourney expanded their creative possibilities, enabling them to visualize unconventional forms and explore aesthetic variations that might not have emerged through manual sketching alone. Yet, some participants expressed concern that AI-generated imagery felt "too similar" or "algorithmically biased," reducing originality and personal expression—echoing findings by Kulishova and Sajek (2025). These mixed reactions underscore the dual nature of AI as both an enabler and a constraint within creative processes.

Regarding **tool limitations**, students described technical challenges when using platforms such as *Fusion 360 AI* and *Rhino AI*, especially when modeling complex geometries. In several cases, AI-generated forms required significant manual correction to meet design specifications, which occasionally negated time savings. Despite this, most participants appreciated the ability of AI to visualize structural feasibility quickly, leading to more confident design decisions.

Finally, **ethical concerns** emerged as a prominent theme. Students questioned issues of authorship, originality, and the potential for plagiarism in AI-generated content. Some worried that AI tools might reproduce existing designs or blur the boundary between individual and algorithmic creativity. These concerns reinforce calls for integrating **AI literacy and ethical training** within design curricula to ensure responsible use of such tools (Pasquinelli et al. 2023).

Integrated Discussion

Integrating findings from both phases provides a holistic understanding of AI's role in collaborative design education. The quantitative data established that AI integration significantly improved creativity and efficiency, while qualitative insights explained **how** and **why** these gains occurred—through faster ideation, enhanced visualization, and data-supported decision-making (Tan et al. 2024; Tammisto 2025). At the same time, qualitative evidence illuminated the **human factors** that quantitative scores could not capture, such as dependency on AI, reduced hands-on engagement, and ethical uncertainty (Kobe et al. 2022).

As figure 5 illustrated. These results align with prior research suggesting that AI augments design workflows by facilitating rapid iteration and exploration (Zhou and Peng 2025; Melker et al. 2025), but also introduce new pedagogical challenges regarding critical reflection and authorship (Parveen et al. 2024). Overall, the findings underscore that AI can serve as a powerful cognitive partner in design education when used within a **structured, reflective, and human-centered framework**—such as Norman's (2013) Human-Centered Design (HCD) model. This alignment ensures that AI supports rather than supplants human creativity, fostering balanced, ethical, and innovative design learning environments. The study demonstrates that AI's success is contingent on its role as a subordinate tool within a human-centric process. When it accelerates ideation and handles repetitive tasks, it aligns with HCD by freeing the designer to focus on user empathy and complex decision-making. Conversely, when its use leads to uncritical adoption, it undermines the very human values that HCD seeks to prioritize. Therefore, the HCD model provides not just a pedagogical guide but also a critical metric for evaluating the appropriate integration of AI, ensuring it supports rather than supplants human creativity.

Conclusion

This study concludes that the structured integration of Artificial Intelligence (AI) tools in Industrial Design Final Year Projects (FYPs) significantly enhances workflow efficiency, fosters creativity, and elevates design outcomes. Our findings demonstrate that AI serves as a powerful cognitive partner, accelerating research, ideation, and prototyping, which allows students to dedicate more effort to conceptual development and collaborative refinement.

However, this potential is tempered by significant pedagogical risks, including over-reliance that can diminish originality, reflective thinking, and hands-on craftsmanship. Ethical concerns regarding authorship and data privacy further complicate its adoption. Grounded in Norman's Human-Centered Design (HCD) framework, this study posits that AI must function as an enabler of human creativity, not a replacement for it.

The primary practical contribution of this research is an evidence-based model for integrating AI within a reflective, human-centered pedagogical structure. To operationalize this, we propose that Industrial Design education must move beyond ad-hoc tool adoption and formally incorporate AI competency and critical evaluation modules into the curriculum. These modules should guide students to use AI not as an oracle, but as a provocation—a tool to be critically interrogated and thoughtfully integrated within the iterative design process.

For educators and curriculum designers, this study provides a clear framework and a set of critical considerations for harnessing AI's benefits while mitigating its risks. Future longitudinal research is needed to examine the long-term impacts on skill development. By anchoring AI integration in the core values of empathy, critical thinking, and originality, Industrial Design education can strategically evolve to embrace technological innovation without compromising its human-centric foundation.

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Collaborative language learning through generative AI

The case of French

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Abstract

The introduction of generative AIs to education has reinitiated discussions of how humans are involved with technology and how altered human-AI collaboration transforms education. In this paper we investigate shifted material relationships and ecologies of language learning through a project in which teacher students were introduced to generative AIs and experimented with ways in which they could be used in classrooms as part of placements in schools. The paper draws on classroom observations and interviews with teacher students in order to understand how prospective language teachers reflect on and use generative AIs, and on sociomaterial perspectives to understand how classroom didactics are formed by these uses. Our analysis centers on a specific example of how French was taught to 6th formers using text and image generation in a complex material set-up that connected natural artefacts with AI technologies to teach children French vocabulary.

Keywords: language learning, generative AI, sociomaterial perspectives

Introduction

In this paper we investigate ways in which generative AIs (GenAIs) become part of the dynamics of teaching French to 6th formers, following a research and development project in which teacher students were introduced to GenAIs and experimented with ways in which they could be used in classrooms[1]. Our research addresses a growing need for empirical understandings of how GenAIs enter, form, and affect schooling (Bruun et al. 2024). GenAIs enable collective learning processes as they are technologies that offer enhanced production of automated text, translation and creation of images through prompting, thereby blurring the boundaries of human and digital agency (Thorne 2024). In the paper we investigate these human-AI collaborations in the context of sociomaterial practices of language learning, in which GenAIs are organized, connected and hybridized with other actors in the classroom.

Theoretical considerations

In working with generative AIs in language learning we draw on sociomaterial approaches recently introduced into research in language education. These are theoretical frameworks that can help us analyse collaborative human-AI relationships that challenge existing human-centered perspectives in education. Studies by for instance Godwin-Jones (2024), Thorne et al. (2021), Ou et al. (2024), Toohey (2018), Pennycook (2018), Meyer (2024), thus from various perspectives both critique and explore issues of cognition, sociality and human agency central to the fields of second language learning and linguistics drawing on sociomaterial approaches. Central to these contributions is a posthuman perspective that challenges human-centric ways of thinking involved in language learning (Ou et al. 2024). Following a relational approach to language learning, sociomaterial approaches investigate particular arrangements in practice that involve both human and non-human actors, e.g. teachers and pupils as well as technologies, tables, chairs and multiple artefacts involved in learning. What sociomaterial studies have brought to research in language learning is therefore both problematizations of the idea that language resides in individuals'

minds or in social interactions, and enhanced perspectives on the significance of materiality in learning, including the materiality of language itself (McLure 2013; Sørensen 2009).

With regard to the study of GenAIs in language learning sociomaterial approaches contribute with analytical perspectives on intensified, collaborative relationships between humans and technologies in learning. Godwin-Jones (2024) significantly describes these changes as *dynamically shifted ecosystems for language learning* initiated by the integration of GenAI in teaching and learning as GenAIs have the capability to perform social actions (e.g. writing) usually associated with human actors. As digital actors, GenAIs thus challenge existing concepts of agency and intelligence.

In addition to analyzing the role of agency we focus on the role of *translation* in our data as translation appeared as a general principle for teaching French vocabulary. Thus, the teacher students we observed used a didactic principle of exposing pupils to multiple repetitions of the chosen vocabulary, building on the idea that learners need to encounter vocabulary repeatably and in different contexts in order to learn (Stæhr 2019). Translation therefore involved integrating French vocabulary into multiple spaces, materialities and activities, including machine translation and image generation through GenAI (Vinall and Hellmich 2022; Vartiainen and Tedre 2023).

In analysing processes of translation involving GenAI, we draw on Leander and Lovvorn (2006), who from a sociomaterial perspective explore how literacy practices shape educational environments. Drawing on Latour (1999), Leander and Lovvorn define translation as a dynamic of practice in which actants are transformed by relationships to other actants in the network of practice. To be an actant therefore means "…shifting in space and time, which involves the translation of actants as they circulate, are recruited, organized, and hybridized with other actants" (2006, 296). Translations in this understanding define classroom rhythms, as Leander and Lovvorn in their study observed how teaching often required that pupils moved texts from one material-textual space to another, e.g. from the whiteboard or a textbook to the space of their own printed pages. These sociomaterial relationships translated pupils' work into routinized activities in which pupils' agency was often limited. We argue that a similar rhythm can be observed in our data, however,

learner-centered didactics to some extent altered this rhythm, with GenAIs providing both enhanced productivity and automated productions of language through pupils' prompting.

Data and methodological considerations

Our analysis draws on observation data and group interviews from a project in which teacher students worked with generative AIs in their classes at teacher college and in their practicums in elementary schools (Hasse 2011; Halkier 2020). The purpose of the project was to enhance teacher students' awareness and didactic engagement with GenAIs, as future teachers need to critically engage with the uses of GenAI in schooling.

In the project GenAIs were introduced into teacher students' everyday learning rhythms in the course of two semesters in 2024, where we followed two classes of English students and one of respectively German and French students. Both independent platforms such as ChatGPT and Copilot and integrated AI functions in Padlet (image generation through "I can't draw") were used. As teacher students need to work with data-safe material in schools, we also chose to work with SkoleGPT, a GPT developed by the participating teacher college to use in schools (skolegpt.dk).

In addition to workshops and observations, we did fieldwork in schools, using observations in classrooms and subsequent interviews to understand students' uses of GenAIs in schools with pupils. Thus, the students' semesters were characterized by their shifting participation in courses at teacher college and in specific schools where they were in practicum. Multisited ethnographies (Marcus 1995) of these movements were therefore central to our research, as they enabled us to trace emergent configurations and relationships between generative Ais and language learning.

In this article we focus primarily on classroom observations of two lessons in a 6th form class, where the following GenAIs were used together with other learning materials to teach French vocabulary: SkoleGPT (text-to-text translation Danish to French) and Padlet's image generator (prompted French text to image generation).

Into the field – French as a school subject

In Denmark, French is, depending on pupils' choice, a second or third foreign language that is taught from the 5th form[1]. In schools, French is often taught in small groups of pupils who may have been brought together from different classes or different schools, as not all schools have French teachers. French thus emerged as a significant case for this paper, as we were interested in studying how generative AIs can contribute to the teaching of a language that has a relatively marginal position in the curriculum, and which is generally not supported by pupils' access to the language in their immediate environment.

In the teacher's college we followed two teacher students, who were working together in their practicum period at a suburban school near Copenhagen. Data from this part of the research were learning materials the teacher students shared with us, observations of two French lessons in a sixth form class, and two interviews with the teacher students. The first interview was made right after the lessons observed, in which the teacher of the French class was also present, and a second interview was made a couple of weeks after the teacher students had repeated the lessons with a 7th form class, which we unfortunately were unable to participate in. Interviews were based on the teacher students' narratives of their didactic ideas and on reflections on the lessons observed, with a specific focus on how and why they had chosen to use GenAI.

Didactic perspectives and the role of GenAI

In working with generative AIs in French the teacher students chose to support the pupils' engagement in French by associating it with multiple both technical and natural phenomena and by focusing on pupils' production of language and aesthetic products. Didactically, the teaching was as mentioned based on a principle of repetition, the purpose of which was to help pupils both remember and use words in specific contexts (Stæhr 2019). Thus, French vocabulary was circulated in a number of different contexts, which connected French vocabulary with both natural objects and generative Ais and which allowed pupils to work with language both receptively

1 From the school year 2025/2026 French will be offered as a compulsory second language taught from the 6th form

(e.g. reading) and productively (e.g. writing). Teaching activities were scaffolded by the teacher students in various ways, e.g. by using printed vocabularies and by supporting pupils' prompting in class.

First of all, the teacher students had a specific focus on moving the teaching out of the classroom by situating some of the lessons in nature (Hartmeyer and Præstholm 2021). The purpose of this strategy was to allow the pupils to be physically active and use their senses while learning French. Thus, the teacher students had planned lessons in the classroom that included materials from a nature project made the week before in a nearby bog-area. During this outing, pupils foraged for feathers, leaves and twigs to create Mandalas, a geometric shape representing the universe and used for e.g. meditation, relaxation and creativity (Perplexity AI 2025). In creating the Mandalas, the pupils were introduced to French vocabulary relevant to the outing and the making of the Mandalas. A printed plastic covered sheet of vocabulary entitled *Vocabulaire sur la forêt* illustrated with images was brought into the outing and used for identifying objects in nature (fig. 1). In class,

	Une branche	[brongsj]
	Une baguette	[bagæt]
	Un tronc d'arbre	[tråŋk darbr]
	Un arbre	[arbr]

Figure 1. Examples of French vocabulary from the sheet used in the outing to the bog[2]

the work of engaging with vocabulary by relating it to objects was engaging with vocabulary by relating it to objects was extended, as the outing and creation of the Mandalas was integrated into a complex dynamic of translating vocabulary into text and images, some of which were AI-generated.

The two lessons we observed were divided into four activities, two of which were GenAI-based. The first activity was a warm-up and served as a recall of the outing made to the bog. Pupils were organized in pairs and were asked to talk about what happened in the outing. The pupils were then asked to write a story in Danish about their outing, which was to be used in the next activity.

Figure 2. Pupils' Mandalas made from objects in nature and a GenAI-created Mandala (right) based on the natural Mandala (left)

Activity two focused on the pupils uploading their story to SkoleGPT and prompting the chatbot to translate their story from Danish into French. The translated stories were subsequently shared on a Padlet which was exhibited on the classroom smartboard. For the third activity pupils were invited to come up to the smartboard and put a circle in red around the French words they recognized and knew (figure 3). A brief plenary session where pupils were invited to talk about the vocabulary they identified ended the third activity and in many cases provided a recall of vocabulary used in the original outing. The fourth activity, which was initiated in the second lesson, involved a recreation of the Mandala made in the bog using Padlets' GenAI function. For this activity pupils were asked to prompt the image generator to create images that represented their

Mandalas in as much detail as possible (figure 2). This entailed using French words for numbers and for objects used in the Mandala, for instance "three feathers", "four sticks" etc. Throughout the work with GenAI (SkoleGPT and Padlet) the teacher students scaffolded pupils' activities by suggesting ways of prompting, ie examples of prompts were written on the blackboard next to the smartboard. Finally, the Mandalas were compared in class to see how pupils had succeeded in using French for prompting an AI-representation of their original Mandalas.

La semaine dernière, j'étais en forêt et moi et mon ami avons sauté au-dessus d'un ruisseau, mais sa jambe droite est tombée dans l'eau. Afin de l'aider, j'ai cherché une solution et nous avons créé un mandala avec des feuilles et des branches. C'est une

Figure 3. Pupils noticing vocabulary from GenAI-translated text (right)

Analysis

Dynamics of translations and circulations

Observations of the class activities revealed a number of translations and circulations of materials that established connections across heterogeneous learning spaces. Circulations included multiple relationships between natural and digital materials (e.g. twigs, leaves and AI generated texts), reinventions and reconfigurations of objects (e.g. AI generated images of the Mandalas) and identifications and translations of natural objects as well as (Danish) text (into French). In these circulations of different materials pupils produced both aesthetic representations of collected objects (the Mandalas), reinventions of these collections (the AI generated Mandalas) and vocabulary, texts and stories in Danish and French (and other languages as well). In these activities, however, pupils did not act alone, but were part of extensive arrangements in which GenAIs, Padlets and the smartboard formed learning practices.

As described above translation was a general principle of the teacher students' teaching, as French vocabulary was repeatedly

circulated between different learning spaces and materialized in different ways. First of all, French vocabulary (the printed vocabulaire) contributed to translating objects in nature by providing pupils with words and images for the things they collected and identified to make the Mandalas. In turn, objects found in nature by the pupils were translated into Mandalas, i.e. aesthetic objects that materialized and situated French vocabulary in ways that made it more playful and embodied. Moving into the classroom, translations of the natural environment and pupils' experience with it were enacted through stories in Danish that were transformed into text and subsequently into French by using SkoleGPT. Interestingly, many of the pupils did not have prior experience with SkoleGPT (or other AI technologies) and therefore experimented with the GPT by transforming their story not only into French, but also, we observed, into eg Japanese and Chinese. One pupil who had a Somali background, proudly showed us by pointing to his screen that SkoleGPT had been able to translate his and his classmate's story into Somali. In this way SkoleGPT generated translations that engaged pupils' awareness of languages as well as their feeling of identity.

Subsequent translations were made in the classroom by sharing stories in French through Padlet and the smartboard and by translating natural objects and Mandalas into AI generated images. Thus, translations operated through the mobilization and relationship of several materials and activities and were not only language and text borne but multimodal.

In this complex chain of relationships and heterogeneous configurations translation served a number of purposes that enhanced the teaching and learning of French as follows. First of all, chains of interwoven activities created rhythms of repetition, in which vocabulary was continually reenacted, but in new ways to both didactically maintain and vary learning over time. Using multiple modalities (text, visuals, both AI-generated and learner-generated) for instance materialized French vocabulary in different ways, linking eg the aesthetics of Mandalas to French words for numbers (see fig 2 & 3). Secondly, heterogeneous relationships served to organize and hold together activities across time and space, thus connecting for instance the natural environment with the classroom. Observations in the classroom showed that pupils had enjoyed the outing to

the bog, but that some of them struggled with recalling the specifics of the trip. Producing the copied vocabulaire and images of the pupils' Mandalas in class helped pupils recall, and subsequent translations of the outing and its gathered materials reenacted the outing in new ways.

Finally, chains of translations connected French with activities and materials that were unusual to the teaching and learning of French. As mentioned above, Danish pupils do not have access to French in their immediate environment, however, the outing to the bog established French as part of the local natural environment. In addition to this, SkoleGPT gave pupils access to French through translation, and thereby enabled them to produce more (written) language than they would have been able to produce on their own, as beginners.

Agencies and collaborations

Our empirical example has identified ways in which French vocabulary became involved in complex ecosystems for the teaching of French as well as extending its reach beyond the classroom. Complex ecosystems of teaching French thus involved shifting forms of agency, in which pupils were positioned as both producers of language and of images, but also as co-authors and co-creators with generative AIs. At the outset, the teacher students had, as mentioned, planned the activity as one in which pupils were meant to be actively involved. Using nature as a learning environment for instance positioned pupils as actively involved in discovering and engaging with nature while learning French. Learner agency was also supported by the making of the Mandalas which was planned to support aesthetic learning.

GenAI thus entered and participated in complex ecosystems in which vocabulary was continually circulated and which created multiple environments for learning French vocabulary. Agency was in these shifting learning environments collectively enacted, as heterogeneous (digital and analogue) materials worked together with pupils and their student teachers to create potentials for learning. Looking specifically at the GenAIs incorporated into these ecosytems, we can argue that translating pupils' text with SkoleGPT provided enhanced and personalized textual production that could not have been created by pupils alone. Pupils' collaboration with

SkoleGPT thus produced automated writing that significantly exceeded their capacity for writing in French as beginners in terms of both the scale and variation of vocabulary used (see fig 3). This was confirmed by the interviews with the teacher students who described the pupils' vocabulary as limited. The production of personalized text for noticing French vocabulary was therefore a collective endeavor, involving both teacher students' drafted prompts on the blackboard, pupils' prompting and translations of text into multiple languages and SkoleGPT's machine translation. In this co-production of automated text and pupils' prompting, pupils were positioned as producers of text based on their personal stories but were also part of SkoleGPT's automated text creation that moved agency from the pupil(s) to the arrangements involving the teachers, the blackboard, and SkoleGPT. Significantly, these relationships were only partly reflected on by teacher students and pupils in the classroom, where pupils' texts were primarily used for noticing vocabulary, and machine translation was therefore to some extent seen as a transparent activity.

With regard to the production of Mandalas, Padlet's GenAI function became significantly involved in (re)creating pupils' natural Mandalas, producing a different configuration of aesthetic creation than that of the outing. Producing Mandalas through GenAI was thus driven by relationships between Padlet's algorithms, pupils' prompting with French vocabulary and teacher students' prompt drafts written on the blackboard. Rather than engaging in the process of being and foraging in nature, the creation of Mandalas in the classroom was therefore an activity involving pupils, teachers and AI functionalities, resulting in a multimodal expression of co-creation. Though sociomaterial relationships were involved in both activities of creation (in nature and in the classroom), prompting Padlet's image generator placed Padlet's algorithms at the center of creative agency, thereby distributing the creative process between humans and GenAI. Thus, though pupils to some extent created images of their mandalas by prompting the image generator, specific color choices and other visual outcomes were formed by the AI (see fig. 2).

As with the production of text described above, the significance and effect of these shifted agencies was only partially reflected on in the classroom, where teacher students and pupils primarily dis-

cussed how AI-generated Mandalas compared to the Mandalas created in nature, ie the activity focused on the aesthetic products and the target language rather than the contribution of the GenAI technology. Though this in many ways makes sense in the context of teaching French to 6th formers, it also raises the question of how we can address the (co)agencies of GenAI in education, and specifically in language education, where prompting and multimodal production is intimately associated with linguistic competence and agency.

Discussions and conclusions

In this paper we have used sociomateriality as an analytic concept to understand how generative AIs are enrolled in schooling and become collaboratively involved with pupils and teacher students in the classroom. Following a specific example of how French was taught to 6th formers we have argued that GenAIs should be seen as part of the arrangements that make up the specific rhythms and spatial configurations of teaching in schools. This is significant as focusing on GenAI as defined relationally by specific practices will help us understand how these technologies contribute to and transform e.g. student agency in language learning. Thus, our example shows how teaching French vocabulary became a complex sociomaterial activity, where vocabulary was circulated in different ways to support pupils' continuous engagement with French as a target language. Based on Leander and Lovvorn we argued that the circulation of French vocabulary became an act of translation, where vocabulary became *recruited, organized, and hybridized with other actants* (2006, 296) to create both variation and cohesion in teaching and learning. GenAIs became part of these circulations and in significant ways contributed to shifts in the ecology of language learning by both enhancing and automating the creation of text and images used in teaching. As described above, GenAIs therefore became significant actors and collaborators in producing text and imagery in the classroom. However, the process and effect of engaging collaboratively with GenAIs was not clearly addressed by the teacher students as part of the teaching. This raises issues of how we can incorporate reflections on the changing agencies of producing and learning a language in a society increasingly affected by GenAI.

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Notes

1 The project was financed by *The Danish National Centre for Foreign Languages* (NCFF)

2 The two students have chosen to create a transcription that is phonetically as spoken for students in a Danish school context

academic quarter
akademisk kvarter
research from the humanities
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Transformative AI Agency

How Students Negotiate and Collaborate with Generative AI in Higher Education

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Abstract

As generative AI tools such as ChatGPT enter higher education, questions arise about how students can use them not merely instrumentally but as catalysts for collaborative and reflective learning. This study investigates how master's students engage with ChatGPT in group-based academic tasks, specifically when working with complex course literature. Drawing on Vygotsky's concept

of double stimulation and Engeström and Sannino's theory of transformative agency, we analyze how students collectively navigate AI-generated responses, challenge assumptions, and reframe understanding. The data stem from an exploratory case study in a Danish university course and include group discussions, ChatGPT logs, reflections, and focus group interviews. Findings show that ChatGPT mediates not only as a resource but as a mediating artefact that provokes resistance, negotiation, and generative questioning. Over time, students began to use technology not just for answers, but to explore and question ideas together. The study contributes to research on AI in education by highlighting the role of pedagogy in enabling transformative agency through Generative artificial intelligence.

Keywords: Transformative agency, Double stimulation, Generative AI, Higher Education, ChatGPT

Introduction

As generative artificial intelligence (GenAI) tools like ChatGPT become increasingly integrated into higher education, there is a growing need to understand how students use these technologies in pedagogically meaningful ways. While research highlights benefit such as personalization, efficiency, and language support (e.g., Tillmanns et al. 2025; Kasneci et al. 2023), concerns remain about superficial use and the erosion of critical thinking and academic integrity (Cotton et al. 2023; Yang 2024). However, most studies focus on individual use and overlook how students collectively engage with GenAI in transformative learning (Bruun et al. 2025; Yang 2024). Recent work frames GenAI as a cognitive partner that supports explanation, feedback, and reflection, contingent on transparency and trust (Dalsgaard and Prilop 2025; Bruun et al. 2025; Jensen and Dau 2025). Building on this and on recent research on GenAI as a mediator of collaborative knowledge construction (Kaup et al. 2025), we shift the lens from individual usage to collective meaning-making in scaffolded, collaborative settings in higher education. Drawing on socio-cultural theories, we examine how GenAI as a mediating artefact not only supports cognition but also shapes how knowledge is produced, shared, and challenged in collaborative learning. As Paavola and Hakkarainen (2021) argue, technologies can act as

epistemic artefacts: they structure inquiry and become objects of joint reflection and development, especially when embedded in dialogic, object-oriented collaboration. Rather than treating ChatGPT as a static information source, we investigate how it enters the dialogic space between students, as a tool, a problem, and a trigger for negotiation. The research question guiding this article is: *How do students negotiate ChatGPT's role in collaborative learning processes, and how does this engagement support transformative agency?*

To investigate this, we draw on Vygotsky's (1978) concept of double stimulation and Engeström and Sannino's (2010) theory of transformative agency, which together provide a framework for understanding how disturbances in practice, such as ambiguous GenAI outputs, can trigger collective reflection, negotiation, and reconfiguration of learning activity.

Theoretical framework

This study builds on cultural-historical activity theory (CHAT) and conceptual developments around transformative agency and double stimulation. Following Vygotsky's (1978) notion of mediated action, human agency and learning are understood as situated, tool-mediated, and fundamentally collective. From this perspective, artefacts such as GenAI become not just tools for information retrieval, but mediating instruments that shape cognition, interaction, and participation.

Transformative agency is defined as the capacity of individuals or groups to break away from the given frame of action and take the initiative to transform their activity (Virkkunen 2006; Engeström and Sannino 2010; Sannino 2020). Haapasaari and Kerosuo (2015) further conceptualize transformative agency as a process that unfolds through collective negotiation and reflection, often sparked by tensions or disturbances in practice. Drawing on Vygotsky's (1978) concept of double stimulation, they argue that such disturbances (first stimuli) may generate uncertainty or breakdowns, which can trigger new forms of mediated action using second stimuli, cultural tools, concepts or collaborative strategies that enable expansive sense-making and coordinated action.

In this study, ChatGPT is examined both as a source of disruption and as a potential mediating artefact. When its responses are perceived as incorrect, superficial, or ambiguous, they function as first

stimuli that interrupt students' meaning-making. In turn, students create second stimuli in the form of prompts, questioning strategies, or peer dialogue. These stimuli help reframe the task, clarify concepts, and foster critical engagement. Learning is thus not only seen as acquiring knowledge, but as the collective reshaping of technological tools in practice (Haapasaari et al. 2016; Engeström 2001).

Importantly, the pedagogical design of the course also plays a mediating role. As argued by Paavola and Hakkarainen (2021), pedagogical design can support expansive learning by cultivating shared epistemic objects and knowledge practices that promote sustained collaborative inquiry. In our case, group-based discussions and the collaborative use of ChatGPT supported students in articulating concerns, sharing divergent views, and exploring alternative approaches. This process, we argue, is best understood through the lens of transformative agency, as students respond to disturbances and actively redefine their learning activity.

Methodology

This study is based on an exploratory case study drawn from qualitative methods. According to Yin (2014), exploratory case studies are suitable when outcomes are not predefined. The aim is to gain an in-depth understanding of a complex social phenomenon. In this study, we explore how GenAI can facilitate collaborative work between students on course literature and as a mediating tool. Rather than testing a hypothesis, we aim to look at how GenAI tools might support or challenge students' engagement with academic texts. The study explores how students' group-based interactions with GenAI contribute to the emergence of transformative agency in their understanding and negotiation of course content.

Case and context

The study was conducted during a master's-level elective course on *Computational Thinking and Digital Literacy* at a Danish university, part of the master's program in ICT and Learning. The course consisted of five sessions, each four hours long, held during 2024. Ten students (four males, six females) participated. Before each session, students had access to assigned readings. Each session included a lecture followed by collaborative tasks related to the session's

Transformative AI Agency
Camilla Finsterbach Kaup
Anders Kalsgaard Møller
Anders Melbye Boelt
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theme. These tasks culminated in a collective exploration of the literature using ChatGPT. To protect student data, the university provided secure laptops with ChatGPT Enterprise access. This ensured that the chatbot could only access uploaded course literature and not Internet-based information. Over time, the dataset was expanded to allow backward searching across previous readings. Table 1 shows the topic of each of the five course sessions.

Session	Theme
1	The computational future: Introduction to computational thinking (CT) and its historical roots
2	21st-century competencies and CT, with a focus on algorithmic thinking and Brennan and Resnick's model
3	Creativity, problem-solving, and abstraction: Comparing human and machine thinking
4	Computational empowerment and CT in (and beyond) the workplace; gender and stereotypes
5	CT in educational contexts: Broader reflections and critical perspectives

Table 1. Topics for each course session.

Students answered teacher-designed questions during each session and then generated their own prompts for ChatGPT based on the session literature. A collaborative model (Figure 1) structured the sessions, with student dialogue mediated by ChatGPT responses and prompts. The model illustrates how these interactions unfolded in cycles: students discussed assigned readings, posed questions fined their prompts or perspectives. This process created a dynamic interplay between human dialogue and AI mediation, designed to support collective reflection and shared meaning-making.

Figure 1. A didactic collaborative model

During the five course sessions, students worked in rotating groups of 2 to 4 participants, engaging with ChatGPT for 20 to 26 minutes

Transformative AI Agency
Camilla Finsterbach Kaup
Anders Kalsgaard Møller
Anders Melbye Boelt
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per session. Group size and composition varied from session to session to support collaborative exploration of the course literature. The didactic design intentionally alternated between rotating group compositions, scaffolded reflection, and open-ended prompting. This cyclical structure aimed to create epistemic variation and collective ownership of inquiry. Rotating group members across sessions exposed students to diverse interpretative practices and amplified moments of negotiation and reflection.

Data collection

The dataset consists of five types of empirical material collected during the course: (1) audio recordings of group discussions (one per session), (2) the ChatGPT prompts written by students, (3) the corresponding AI-generated responses, (4) two focus group interviews conducted at the end of the course, and (5) written reflections submitted by students after the final session. The focus group interviews were carried out by researchers who were not involved in teaching the course to ensure transparency and reduce potential bias. During these interviews, students were invited to reflect on their experience with GenAI. They were also invited to discuss ChatGPT's role in supporting collaborative engagement with academic literature. All audio recordings were transcribed using Whisper (Larsen 2023) and reviewed manually. Informed consent was obtained from all participants, and all data were anonymized and handled in accordance with ethical research standards (Creswell and Creswell 2018). Throughout the article, participants are cited anonymously (e.g., S1, S2).

Analytical approach

The analytical strategy consisted of two complementary strands: an inductive exploration followed by a theory-driven deductive analysis (Creswell and Creswell 2018). The first strand involved the inductive coding of focus group interviews and students' written reflections. This allowed themes to emerge from the material itself, providing insight into students' experiences and reflections on GenAI. These themes included perceived challenges, collaborative dynamics, and changing roles in relation to academic knowledge and course content.

Building on these emerging patterns, the second strand employed deductive coding using the six dimensions of transformative agency developed by Haapasaari et al. (2014): resisting, criticizing, explicating, envisioning, committing, and taking action. These categories were used as *sensitizing concepts* (Blumer 1954) to trace how students navigated moments of uncertainty, negotiated meaning, and reconfigured their practices in response to AI-generated output and peer dialogue.

This dual approach enabled a richer understanding of how pedagogical design and technological mediation shaped students' transformative agency development across the course. Table 2 presents representative examples from the empirical material, illustrating how the six dimensions of transformative agency (Haapasaari et al. 2014) were manifested in students' interactions with GenAI.

Type of Transformative Agency	Quote	Explanation
Resisting	S1: I think I just have these everyday routines where AI hasn't really been involved before... so I don't see any reason to start integrating it now.	The student expresses rejection of the tool and resists its integration into the learning activity.
Criticizing	S7: If there aren't any reliable sources behind it, you should probably be more critical of what it gives you.	The student offers a critical evaluation of AI's output, pointing out ethical and epistemological concerns.
Explicating	S3: I basically just ask it to summarize the key points and theories in the text… I like having those notes so I can look at them later.	The student explains how GenAI supports internal reasoning processes and makes tacit knowledge explicit.
Envisioning	S6: I could imagine using it, say, in a theory of science context. What would make sense? What kind of take should we apply? I imagine it could offer some suggestions that we could then discuss in our group.	The student imagines new, constructive roles for GenAI in their learning process.

Table 2. Examples of Transformative Agency

Table 2. Examples of Transformative Agency - continued

Type of Transformative Agency	Quote	Explanation
Committing	S9: I think you could get through an entire degree using it for everything.	The student articulates an intention to adopt GenAI as a tool in their future study practices.
Taking Action	S2: There were times when we had to think carefully about how to structure the prompt in the right order to get the kind of response we actually wanted.	The students will modify their behavior based on insights from the collaborative process, actively shaping Gen AI´s inputs.

Findings

Our analysis has generated three themes that illustrate how students' use of ChatGPT evolved from initial skepticism and critique to creative exploration and dialogic reflection. These themes represent different, yet interrelated, expressions of transformative agency.

Theme 1: Challenging AI Interpretations

At the outset of the course, many students expressed trust in ChatGPT's responses, often accepting its interpretation of the course literature without extensive questioning. However, this passive stance shifted as they encountered errors, ambiguities, and limitations in the AI output. These moments triggered instances of *resisting* and *criticizing*, two early forms of transformative agency.

One student reflected on how ChatGPT's explanation of key concepts became confusing and overly verbose: "And abstraction, for example, is about filtering out all the irrelevant parts. […] Because there's just so much irrelevant stuff when you use ChatGPT and have a long thread. […] There's really a lot that needs to be broken down. […] So, we get into decomposition to extract what's relevant." (S3). Here, the student resisted simply accepting the AI's phrasing and instead engaged in analytical unpacking of its output. This moment of breakdown, particularly concerning a central analytical concept, marked a turning point where ChatGPT was no longer treated as an authoritative source, but rather as a problematic artefact requiring critical evaluation and collaborative reinter-

pretation. Another participant reflected on the risk of over-relying on GenAI and becoming cognitively passive: "You might become a bit lazy, in a way, just knowing you have that option. […] It also takes a bit of self-discipline—not to let it take over completely." (S7). This quote illustrates a form of *criticizing*, where the student not only questions the tool's influence but also reflects on their own engagement with it. The comment signals a growing awareness of how GenAI may affect study habits and learning processes.

In some cases, resistance emerged collectively, as students questioned ChatGPT's authority in group settings. When responses seemed too narrow or misaligned with the literature, students paused to critique and reinterpret them together. These moments of shared resistance shifted the tool's role from answer provider to a prompt for collective inquiry, revealing how critical reflection and meaning-making can emerge through peer dialogue and negotiation.

Another key insight was that limitations in AI output sometimes led to productive breakdowns. When ChatGPT delivered vague or partial responses, students were prompted to clarify the question but also analyze their own understanding. As one participant put it: "We prompt it, and it gives us some thoughts back, which we then sit down and discuss further." (S2). This type of joint interpretation echoes what Haapasaari et al. (2014) describe as a reconfiguration of one's role in the activity system. Here, resistance and ambiguity become a starting point for deeper articulation and group-level reflection.

Theme 2: Generating Understanding

While the first theme highlights moments of resistance and critique, the second theme shows how students moved beyond opposition and experimented with ChatGPT in more constructive and exploratory ways.

As the course progressed, students shifted from using ChatGPT simply to retrieve information toward using it as a tool for generative exploration and conceptual play. Prompting evolved from a technical task into an epistemic practice, where prompts were strategically rephrased, challenged, or even deliberately manipulated to elicit surprising or more nuanced responses from the AI. This shift illustrates a movement from surface-level interaction to deep

engagement, marked by envisioning new learning opportunities and taking initiative in how technology was utilized. This development is evident in both students' reflections and in the group discussions. One student described how she started using prompts not just for answers, but to provoke reflection: "I started writing more provocative prompts to see if I could get a different kind of answer. It was almost like playing with it to see what it would come up with." (S6). This kind of experimentation demonstrates envisioning, a willingness to reimagine what the AI tool could do in the learning process. Students were no longer merely following instructions or verifying content; they were reshaping tasks and actively using AI to rethink and challenge dominant interpretations.

A group of students critically reflected on representational bias in image-generating AI. When asked to create an image of a nurse, the output confirmed stereotypical gender roles: "I asked for an image of a nurse, and it was a woman. […] So, it really picks up on gender stereotypes." (S7). This observation led to further interrogation of how the system reproduces cultural assumptions. One student noted a contradiction when the AI refused to generate an image of a homosexual person, claiming it would be discriminatory: "But what it had just done was also, in a way, discriminatory." (S7). Rather than accepting these outputs passively, the group used them as a starting point for critical discussion about normativity and bias in AI systems. These reflections illustrate how students reframed AI tools. They did this by not merely following instructions, but deliberately questioning, repurposing, and challenging assumptions embedded in technological design.

In some groups, the prompting process became collaborative. One student emphasized the value of collaborative learning, noting: "I'm a strong advocate for learning together, because you get so much more out of it than working alone. You can build on each other's thoughts, ideas, and even critical reflections." (S6). This highlights how *taking action* was not only individual but collective, shaped by peer dialogue and the co-construction of knowledge. Prompting was no longer a solitary act; it became an emergent practice embedded in shared reflection. These examples demonstrate how students moved from compliance to creativity, from consuming answers to curating questions, and from isolated prompt-

ing to collaborative inquiry. This shift reflects a more explorative and agentive approach to learning, where prompting becomes a dialogic and meaning-making practice.

Theme 3: Mediated Reflection

The third theme captures how these emerging practices culminated in a deeper form of mediated reflection, where students appropriated ChatGPT as a dialogic partner in meaning-making. We observed how ChatGPT evolved from a static tool to an active dialogical partner in students' collaborative reflection. Rather than simply generating content, AI became a third voice in student dialogues. It mediated their collective reasoning and supported a meaning-making process that transcended individual perspectives.

As several students explained, their interactions with ChatGPT were not isolated but embedded in a collaborative dialogue. One student reflected: "We came up with these questions together collaboratively. Even though AI provides the answer, we're really working together on it." (S5). Another noted how this joint inquiry opened space for deeper engagement: "It also gave rise to new questions… S5 came up with some real gems." (S8). These examples illustrate how prompting evolved into a shared activity, where the students explored and negotiated the AI's responses. In this context, students began to see collaborative AI-supported reflection not merely as a task, but as a meaningful way of thinking and learning together. Their engagement shows signs of reflective practice, while the articulation of tacit ideas in dialogue with AI responses points toward explicating processes. Another student emphasized how the course design's openness contributed to this dynamic. The didactic framing legitimized experimentation and reflection: "And it's also nice to be given permission by the instructors, because then you don't feel like it's terrible or stupid, or whatever you'd call it." (S5). In this quote, we see the coupling between didactic design and transformative agency. We also see how creating a safe space allows students to take intellectual risks and engage in shared reflection. This supports the notion that the transformative use of AI is not solely dependent on the tool itself. Instead, it depends on how it is socially and pedagogically situated.

Concluding Remarks

This study shows how well-scaffolded pedagogical processes can support collective, reflective learning with GenAI, rather than GenAI itself being the driver of transformation. Our analysis shows how students moved from passive acceptance to critical engagement, from simple prompting, and from individual reasoning to collective reflection. Across the three themes, ChatGPT functioned not merely as an informational resource but as a mediating artefact (Vygotsky 1978) that shaped meaning-making processes. It helped students articulate uncertainties, surface implicit assumptions, test interpretations, and co-construct understanding in dialogue with peers. These moments often followed a pattern of double stimulation (Vygotsky 1978): flawed or ambiguous AI responses created disturbances (first stimulus), which students then responded to through peer dialogue, revised prompts, or conceptual tools (second stimulus). These mediated actions enabled them to reframe problems and transform their engagement with course content. This dynamic aligns with Paavola and Hakkarainen's (2021) notion of epistemic artefacts, tools that support cognition but also become objects of inquiry and development within collaborative practices. Rather than simply using GenAI to retrieve information, students appropriated it as a boundary object for exploring, contesting, and reimagining knowledge. Their ability to do so depended strongly on prior engagement with disciplinary concepts and the pedagogical framing of the course. This underscores a central finding: meaningful interaction with GenAI requires both conceptual readiness and a social infrastructure for inquiry.

While earlier studies have highlighted AI's role in supporting individual reflection and summarization (Cotton et al. 2023; Kasneci et al. 2023; Tillmanns et al. 2025), our findings extend this work by showing how transformative agency can develop when students use GenAI to challenge, reframe, and act on knowledge together (Haapasaari et al. 2016). Importantly, prompting evolved into a dialogue practice embedded in collective reasoning, where students explored ideas and reconfigured the role of technology in their learning. At the same time, the study revealed tensions. Some students expressed concerns about overreliance on GenAI and offloading critical thinking. As one participant noted, "it's easy to let the tool do the work." This highlights the need for didactic designs

that support not just access to GenAI but its thoughtful appropriation. Educators play a key role in fostering environments where experimentation and epistemic risk-taking are legitimate.

This study was exploratory and context-specific, with a small sample, and thus cannot support broad generalizations. However, its in-depth, practice-based insights will contribute to the growing body of research on how GenAI mediates learning. Future studies could explore whether similar dynamics occur across disciplines, platforms, or cultural contexts. Longitudinal or comparative work may also reveal how students' agency with GenAI evolves over time. In sum, this study shows how GenAI can support collective, reflective learning when embedded in well-scaffolded processes. Rather than replacing human reasoning, it became a generative element that helped students ask better questions, challenge assumptions, and engage deeply with knowledge and peers.

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Ethical Implications of Generative AI in Collaborative Learning for Decision-Making in Circular Construction

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Abstract

Generative AI (GAI) is increasingly embedded in collaborative learning environments, shaping how students negotiate trust, authority, and responsibility in decision-making. This article examines how students in a circular construction course navigate the potential role of GAI during early-stage, value-laden design processes. Drawing on focus group interviews with interdisciplinary

student teams, the analysis is framed through a socio-material perspective that views GAI as an entangled actor rather than a neutral tool. Findings show that students often position GAI critically, engaging with it as a creative catalyst in early ideation phases, but maintaining professional distance when accountability, traceability, and domain-specific knowledge are at stake. Hesitation and non-use emerge as meaningful forms of ethical positioning, shaping collaborative dynamics as much as active use. The study highlights the need for pedagogical strategies that support students in critically navigating algorithmic authority and integrating GAI transparently and responsibly into collaborative design practices.

Keywords: Collaborative Learning, Socio-materiality, Generative AI (GAI), Ethical Decision-Making, Circular Construction

Introduction

Generative AI (GAI) is rapidly becoming a central actor in both education and professional practice. In learning environments and across industries like construction, GAI is not just supporting how problems are framed, how knowledge is shared, and who gets to decide; it is beginning to shape how problems are understood, how collaboration unfolds, and how knowledge is valued (Johri 2022; Orlikowski and Scott 2008; Cotton et al. 2023; Kasneci et al. 2023). Early-stage decisions in the construction industry about material reuse, life cycle design, and resource coordination, once grounded in humans' collaborative negotiation, are now increasingly co-shaped by algorithmic logic (Leonardi 2012). These early-stage decision processes are not merely technical calculations, but deeply collaborative and value-driven judgments made under pressure and uncertainty – conditions that make the presence of GAI even more consequential (Barad 2007; Jones 2014). In this evolving landscape, students are not merely learning about sustainability - they are learning through entangled processes of human-GAI decision-making that mirror the very complexities of the professional worlds they are entering (Barad 2003; Jensen et al. 2024).

From a socio-material perspective, this article examines how the presence and perceived role of GAI shape the conditions for dialogue, idea evaluation, and shared decision-making (Johri 2022; Orlikowski 2007; Barad 2007). GAI does not act as a neutral tool, but as

a potential actor whose authority must be negotiated, accepted, or held at a distance (Latour 2005; Callon 1999). Students thus learn not only through direct interaction with GAI, but also through the ethical and professional negotiations surrounding its use (Leonardi 2012; Tlili et al. 2023). The black-box nature of GAI, its biased training data, and lack of transparency raise critical ethical concerns (Haleem et al. 2022; Sharma and Yadav 2022). Rather than adopting GAI uncritically, students often question its legitimacy: Whose perspectives are represented, who controls the flow of insight, and under what conditions can its participation be trusted? (Barad 2003; Cotton et al. 2023). Hesitation and non-use can therefore be understood as ethical positioning, where professional judgment determines whether and how technologies are included in collaborative decision-making. Situated within a construction-oriented educational context, this study investigates how GAI tools are used by students to engage in collaborative exploration of circular design. The research question guiding this study is:

How do students professionally position themselves with an ethical judgment in relation to GAI when the technology has the potential to influence decision-making in early-stage circular design processes?

To address this question, the next sections outline two central foundations for the analysis. First, the concept of early-stage decision-making in construction is introduced, highlighting how this phase involves navigating uncertainty, value-laden trade-offs, and collective judgment. Following this, the theoretical lens of socio-materiality is presented to explore how technologies such as GAI are not simply neutral supports, but potential actors that learners may accept, resist, or hold at a distance (Johri 2022; Kallinikos et al. 2012; Barad 2007). Together, these perspectives provide the groundwork for examining how students' positioning toward GAI, including hesitation and selective engagement, shapes and reconfigures collaborative learning environments.

Early-stage decisions making in collaborative construction

When planning and designing buildings, many of the most important decisions are made long before any physical work begins.

These early stages, often called the design or concept phase, set the foundation for everything that follows. What materials should be used? How long should the building last? Can building components be taken apart and reused in the future? These are not just technical choices, they are value-driven decisions that influence environmental impact, financial cost, and social responsibility (Pomponi and Moncaster 2016; Asdrubali et al. 2024). Because buildings involve many stakeholders such as architects, engineers, sustainability experts, and contractors, these decisions must be made collaboratively (Kirchherr et al. 2018).

In recent years, interest in a *circular economy* in construction has grown, emphasizing design for reuse, recycling, and long-term resource efficiency (Ellen MacArthur Foundation 2013; Geissdoerfer et al. 2017). While often framed at a systemic level involving policy, markets, and supply chains (Raworth 2017; Kirchherr et al. 2018), circularity ultimately depends on early project decisions, when overall strategies are still flexible (Vázquez-Rowe et al. 2021). Early-stage construction decisions are not only technical and economic but also reflect underlying values and ethical priorities. Material choices, design strategies, and stakeholder involvement carry consequences for resource use, waste management, and broader social and environmental impacts (Pomponi and Moncaster 2016; Asdrubali et al. 2024). Students must therefore learn to navigate contested, value-laden, and situated decisions (Raworth 2017).

While research on GAI in construction education remains limited, studies in other fields offer valuable insights. Across contexts, GAI often enters early in collaborative processes, accelerating ideation, structuring discussions, and providing creative input, but also introducing new dependencies and tensions around trust, accountability, and epistemic authority Students tend to engage with GAI outputs critically, weighing their usefulness against issues of transparency and legitimacy. (Wei et al. 2025; Liu et al. 2024; Cress and Kimmerle 2023; Kaup et al. 2025). These dynamics resonate strongly with circular design, where early decisions shape long-term outcomes. If accepted uncritically, AI-generated suggestions risk obscuring the ethical stakes of design choices. Critical engagement is therefore essential to make visible the technology's role, its limits, and its implications for shared responsibility.

As GAI becomes increasingly embedded in early-stage construction decision-making, it can no longer be seen as a neutral support tool. A socio-material perspective allows us to examine how learning, agency, and professional judgment are co-produced through the interplay between human actors, technological systems, and material artifacts.

Framing the Socio-material Perspective

Socio-material perspectives challenge the assumption that learning is exclusively human-centered or technologically neutral. The social and the material are mutually constitutive, and learning emerges through ongoing reconfigurations among people, technologies, and artifacts (Johri 2022; Orlikowski and Scott 2008). Technologies do not merely deliver content or support activity, they actively shape what becomes possible to say, know, and do (Suchman 2007; Leonardi 2012). As Orlikowski (2007) emphasizes, everyday organizing is inseparably linked with materiality. Technologies shape actions, relationships, and knowledge in practice, not as external factors but as integral to the field of practice. Even seemingly individual acts, such as a Google search, are *"constituted by the performativity of computers, networks, software, algorithms, directories, databases, and infrastructure"* (Orlikowski 2007). This entanglement is also evident in GAI. Here, materiality is not only located in the interface, but in how the model generates language, suggests alternatives, and interacts dynamically with users. The phrasing, tone, and degree of confidence in each output carry epistemic weight and shape how authority is negotiated in practice. This reflects broader socio-material perspectives on how technologies co-produce meaning and agency (Jones 2014; Dourish and Mazmanian 2012), while recent research demonstrates how these dynamics are intensified in GAI due to the fluency and persuasive coherence of its output (Pelman et al. 2025; Kasneci et al. 2023; Cotton et al. 2023). In this sense, GAI actively participates in shaping how knowledge is accessed, interpreted, and legitimized (Johri 2022; Barad 2007; Latour 2005).

In collaborative learning environments centred on circular construction, these socio-material dynamics become particularly pronounced. Students navigate complex sustainability challenges in settings where agency is distributed across human actors, digital tools, and material artifacts. Following from the socio-material per-

spective, GAI is not a passive instrument in this process; it becomes entangled in knowledge production, sharing, and legitimation (Barad 2003; Orlikowski and Scott 2008), foregrounding design directions, amplifying sustainability framings, and subtly reorganizing the visibility of ideas. In doing so, GAI may shape who speaks, which ideas gain traction, and how collaborative reasoning unfolds (Callon 1999; Law 1992; Johri 2022), while participating in the emergence of meaning, authority, and judgment within the group (Barad 2007; Jones 2014).

Methodology

To explore how students position themselves professionally and exercise ethical judgment when using GAI in early-stage circular design decision-making, this study draws on a case-based learning context in a professional bachelor's program in architectural technology and construction management at a Danish University College. Students, working in interdisciplinary teams, developed circular design strategies for multi-storey buildings under realistic project constraints. The teaching approach was rooted in reflective practice-based learning (Horn et al. 2020), aiming to strengthen professional judgment and the ability to navigate uncertainty. Students applied decision-making models under time pressure and incomplete data, balancing technical options, client needs, and environmental concerns. Digital tools, including BIM platforms and GAI technologies such as ChatGPT and Microsoft Copilot, supported exploration, scenario simulation, and assumption testing without being presented as solutions.

Research Approach

The study was guided by an exploratory case study design, with a dual focus on how students experience early decision-making in circular construction and how GAI influences collaborative learning processes. Twelve student groups, each consisting of four to five students, participated in the course. From these, four groups were selected for in-depth focus group interviews to reflect diversity in project experiences. The selection considered differences in design strategies, collaborative dynamics, and the extent to which groups engaged with or reflected on the role of digital tools such as GAI. Each selected group worked on a shared design brief during the

design phase of the project. The four groups were interviewed separately, with all members of each group participating simultaneously in their respective sessions. Each interview lasted about an hour and focused on students' reflections on group decision-making, engagement with GAI tools, and how decision models shaped their handling of uncertainty and coordination. All participants gave informed consent, and anonymity was ensured. Interviews were recorded, transcribed verbatim, and analysed thematically (Boyatzis 1998; Saldaña and Omasta, 2016).

The analytical process proceeded in three stages that combined close reading with inductive thematic analysis based on a socio-material perspective (Saldaña and Omasta, 2016). **Stage 1**: The transcripts were first read and discussed to identify recurring elements related to trust, authority, and GAI's role, then coded line-by-line to capture how students positioned GAI in relation to professional reasoning, responsibility, and group dynamics. **Stage 2**: Drawing on the patterns identified in Stage 1, the analysis moved beyond line-by-line coding to a focused comparative coding phase, examining how these positioning practices varied across groups and contexts, and how they related to emerging themes of professional judgment. **Stage 3:** Codes were finally clustered to reveal patterns in negotiations of epistemic authority. Orlikowski's enactment lens (Orlikowski 2007) guided the analysis, tracing how agency, meanings, and roles were continuously configured through practices, tools, and interactions, rather than treating humans or technology as fixed entities.

Analysis of socio-material dynamics

This section presents insights from an exploratory case study of how students in a professional bachelor's program used GAI tools to navigate early-stage decision-making in circular construction. The analysis is organised around three interrelated themes that illustrate how collaborative early-stage design decisions are shaped not only by technical considerations but also by trust, traceability, and professional judgment. The students' interactions revealed tensions around authority, responsibility, and the ethics of digitally mediated decisions, highlighting the challenge of balancing GAI use with critical judgment in uncertain, value-laden contexts.

Circularity as an Ethical Learning Challenge

A substantial part of students' decision-making unfolded without actively using GAI. Many perceived its output as too generic, insufficiently traceable, or misaligned with the technical specificity required in early-stage circular design. As noted by Cress and Kimmerle (2023), students often negotiate the epistemic role of GAI critically, withholding full integration when transparency and context are lacking. Non-use thus became a deliberate part of their reasoning rather than disengagement. From a socio-material perspective, holding technologies at a distance is itself consequential, shaping which human, material, or technological actors participate in the design process (Kaup et al. 2025). This becomes evident in students' reflections on the role of materials themselves.

> "Well… we've chosen materials with a long lifespan—like 50 years plus in most places. And you could say we chose brick for the facade instead, because we had talked about whether it should be wood or something else. But then there's the maintenance and… operation and maintenance that comes into play instead."

Students thus recognized that early-stage design decisions in construction were not only technically significant but also entangled with ethical and material considerations. Their reflections highlight how materiality, both the properties of materials and the availability of data, actively shapes collaborative decision-making (Orlikowski 2007; Barad 2003).

This illustrates how material choices (materiality) and the information available about them participate in shaping discussion and decisions, rather than being passive objects of choice. The uncertainty surrounding durability and maintenance demonstrates that practice is co-constituted by both human actors and material/technological factors (Suchman 2007; Orlikowski and Scott 2008).

Generative AI and the Redistribution of Epistemic Authority

Students engaged with GAI tools such as ChatGPT and Copilot with a mixture of curiosity and skepticism (Kasneci et al. 2023; Cotton et al. 2023). Some used GAI to jumpstart creative ideation or explore unfamiliar design options, while others expressed concern

about relying on outputs they could not verify: *"But document it? I actually think that's hard with it. If you've just asked it. It's really about making sure we can document the decisions we make, not just 'because the GAI said we should."* This ethical hesitation highlights the socio-material entanglement of GAI in collaborative decision-making. When AI-generated content shapes group outcomes, questions of accountability and responsibility become distributed across both human and technological actors. One student critically reflected on the perceived objectivity of GAI:

> "Well, if you go and ask an GAI about fire safety compared to something else, you don't actually know. Because the data—or what it gives you—it's just to satisfy us. It's not like it actually got it from the updated B18 version from this specific date."

Students also described how GAI's confident tone could influence group momentum, even when information was incomplete or potentially misleading (Haleem et al. 2022; Hassan et al. 2022; Pelman and Zoran 2025). As one remarked: *"I don't know… I mean, I think we generally actually… like, we've always thought about what it is we're getting out. There's nothing we just directly take as it is."*. This indicates that GAI was experienced and negotiated as a socio-material actor that could influence which ideas gain legitimacy, and how knowledge is mobilized in collaborative processes (Orlikowski and Scott 2008; Barad 2007; Leonardi 2012; Suchman 2007). A similar effect is documented by Wei et al. (2025), who found that GAI can accelerate group creativity and problem-solving but simultaneously shift cognitive responsibility away from students. In this sense, GAI reconfigures epistemic authority within the group, influencing both the flow and outcome of shared decision-making (Johri 2022; Pelman and Zoran 2025). Students were acutely aware of these dynamics. They noted that the lack of traceability and transparency in GAI outputs posed barriers to trust:

> "It's about sources, references. If you had one [a GAI] that was only fed with valid sources… then you'd trust more what it comes up with."

Together, these reflections illustrate a pedagogically significant tension where students want GAI to support learning, but uncritical reliance risks blurring responsibility and weakening shared ethical accountability (Liu et al. 2024). From a socio-material perspective, these dynamics exemplify how learning and ethical judgment co-emerge through the entanglement of human actors, materiality (including GAI outputs), and collaborative practice.

The Temporal Dynamics of AI in Collaborative Design

While the socio-material perspective underpins the entire analysis, this section focuses specifically on how students positioned GAI during different phases of their collaborative design process. In particular, it examines how GAI entered as a creative catalyst in the early stages, how its influence persisted in subtle ways over time, and how students negotiated its role as they moved from ideation to more detailed decision-making. Whereas the earlier section focused on students' ethical positioning and concerns about GAI reliability, the present analysis highlights how GAI's role shifted during the collaborative process.

The way students used GAI was shaped by its perceived role in the group. For many, GAI acted as a starting point for brainstorming or visualizing concepts, particularly in the early phases of design (Kasneci et al. 2023). One group described how image-generation tools provided early aesthetic direction, but without deeply influencing the final decision-making:

> "Well, the competition or tender material we got—we just put it into ChatGPT and asked: 'Can you suggest a building expression?' and also shaped it in relation to what I had experienced. Then it came up with some different examples, and you could try out various things to focus on. It actually works quite well. Like, it kind of kickstarts your imagination about what you could do, I think."

Here, GAI functioned more as an inspiration generator than a decisive authority. Yet its presence still shaped the group's focus and introduced frames for exploration, illustrating the socio-material co-constitution of attention, creativity, and decision-making (Johri

2022; Pelman and Zoran 2025; Barad 2003; Dourish and Mazmanian 2012). As students moved from loosely structured ideation to more detailed analysis, GAI's influence often faded, but it lingered in subtle ways. One student reflected on the lingering effects of AI-generated visuals: *"Very subconsciously, I think maybe some of those image's kind of stuck with us when we moved into the decision-making phase."* This demonstrates how socio-material entanglements evolve through time. GAI may enter early as a creative trigger, but leave subtle imprints that shape subsequent human deliberation (Kaup et al. 2025, Barad 2007; Orlikowski and Scott 2008). At the same time, students began developing practical strategies to manage GAI's role over time. While their concerns about accuracy and hallucination relate to the epistemic issues discussed above, here the emphasis shifts to how they actively try to mitigate these uncertainties. Students expressed a preference for systems that integrate verifiable sources and align more clearly with the regulatory context of construction (Johri 2022; Pelman and Zoran 2025; Sharma and Yadav 2022; Cotton et al. 2023). For instance, the importance of a traceable GAI experience was emphasized:

> "It's about sources, references. Where you get your sources from. […] if you had one that was a bit more closed off from the internet and only fed with valid sources that you could trust – then […] you'd trust more what it gives you, when you're not yourself unsure if it's just making things up."

These reflections illustrate a shift from seeing GAI as a one-way information provider to conceiving it as a collaborative partner; one that must be explainable, reliable, and ethically embedded in the workflow. In socio-material terms, students negotiate with both the social (peers, roles, discussion) and the material (AI outputs, interfaces, generated content), co-constituting knowledge, attention, and ethical reasoning throughout the design process (Wei et al. 2025; Orlikowski 2007; Barad 2007; Leonardi 2012).

Conclusion

This study explored how socio-material dynamics involving GAI shape students' collaborative decision-making in early-stage circular design. Our findings show that GAI affects information flow and the negotiation of authority, responsibility, and ethical positioning within interdisciplinary teams (Johri 2022; Orlikowski 2007; Barad 2007). Students often used GAI as a creative catalyst in early ideation, but maintained critical distance when traceability and accountability were required. Hesitation and non-use reflected deliberate strategies to protect professional judgment and shared responsibility (Cress and Kimmerle 2023).

Through a socio-material and enactment lens, the analysis reveals how learning, ethical judgment, and epistemic authority emerge through the entanglement of human actors, GAI outputs, and material factors. Even subtle technological inputs redistribute attention, influence reasoning, and shape collective decisions, highlighting the co-constitution of social, ethical, and material elements in practice.

These insights point to the need for pedagogical strategies that integrate GAI as an active participant in collaborative reasoning rather than a neutral tool (Latour 2005; Orlikowski and Scott 2008). Structured opportunities to critically engage with GAI, support professional judgment and ethical reflexivity, preparing students to navigate black-box technologies responsibly while maintaining accountability and collaborative integrity (Jones 2014; Sharma and Yadav 2022; Wei et al. 2025).

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Artificial Intelligence-Generated Vignettes as Triggers for Collaborative Reflection

Exploring Methodological Potentials in Higher Education

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Abstract

Given the ongoing digital transformation of professional practice, educators increasingly require tools that can scaffold collective reflection on ethically complex dilemmas. This study examines the methodological potential of generative AI (GenAI)–produced video vignettes as boundary objects for fostering collaborative reflection and professional judgment in pre-service education. In a qualitative case, pre-service social educators engaged in group discussions and written reflections around a GenAI-generated scenario designed for ethical ambiguity and professional recognizability. The analysis shows how the vignette's multimodal features activated dialogic exchange, supported negotiation of perspectives, and enabled the emergence of shared professional reasoning. Framing the GenAI vignette as a methodological artifact, the study extends vignette-based pedagogy by specifying affordances that intensify collective sense-making. We argue that GenAI vignettes can effectively scaffold dialogical reflection and context-sensitive judgment in technology-mediated settings, positioning GenAI as a co-creator of reflective spaces that enrich practice-based learning and the development of professional judgment.

Keywords: Vignettes, Generative Artificial Intelligence, Boundary Crossing Object, Higher Education, Reflective Practices

Introduction

Professional education programs increasingly require methodological tools that can scaffold collective reflection on ethically complex challenges. Across the welfare professions, digital transformation is reshaping the conditions for care, judgment, and pedagogical practice. Technology is no longer merely a tool but a mediating and transformative force in how professionals act, decide, and relate. As a result, technological literacy has become a core competency, not just technical proficiency, but critical, ethical, and reflective engagement with technology (Wallace 2011).

Reflection plays a crucial role in cultivating this capacity. Schön (2017) conceptualizes reflection-in-action as a situated response to uncertainty, where professionals explore, test, and reframe their understanding while still immersed in the situation. Similarly, Horn et al. (2020) emphasize that reflective practice unfolds in a negotiation

between experience and inquiry, particularly in contexts of ethical uncertainty. However, reflection in professional education often risks becoming superficial or individualistic (Brown et al. 2013; de la Croix and Veen 2018). Meaningful reflection requires an activating trigger and a space for dialogical sense-making (Bagheri et al., 2019; Schuler 2021).

Vignettes have long served as pedagogical tools to stimulate reflection and ethical deliberation. Traditionally composed as brief written scenarios, they enable students to engage with fictional yet realistic dilemmas without personal exposure (Demetriou 2023). Vignettes can create shared, low-risk arenas for exploring professional judgment when designed with ethical complexity and professional relevance. Recent work highlights their role as boundary objects, artefacts that support shared reflection while allowing interpretive flexibility across professional, experiential, or disciplinary boundaries (Star and Griesemer 1989; Jenkins et al. 2020). The rise of generative artificial intelligence (GenAI) presents new opportunities to reimagine the vignette format. GenAI can generate vivid, affectively rich, ambiguous video scenarios that engage students more deeply than static text. Such multimodal vignettes may foster more responsive, collaborative, and situated reflection, particularly in group settings where ethical dilemmas are negotiated collectively. In this way, GenAI becomes a tool and co-creator of reflective spaces. Accordingly, our interest is not in students' views on AI per se, but in the methodological affordances of GenAI-generated vignettes for structuring and intensifying collaborative reflection. This article therefore asks: *How can GenAI-generated vignettes function as methodological tools to foster collaborative reflection and the development of professional judgment in professional education settings?*

To address this question, we draw on an empirical study of preservice social educators who participated in a focus group and wrote reflections centered on a shared GenAI-generated video vignette. We analyze how the vignette's multimodal and affective features elicited dialogic exchanges, negotiated perspectives, and emerging shared reasoning. The following section develops the theoretical frame guiding our methodological focus, centering on reflection-in-action (Schön 2017), boundary learning mechanisms (Akkerman and Bakker 2011), and the role of shared artefacts in collaborative professional learning.

Theoretical framework

In this study, reflection is conceptualized as a professional and situated response to complexity and uncertainty. Drawing on Schön (2017), we understand reflection as a practice-based process through which professionals engage with ambiguous or problematic situations by critically examining their actions (*reflection-in-action*) or revisiting them retrospectively (*reflection-on-action*). Schön's framework foregrounds how practitioners learn and develop judgment not through abstract reasoning, but through situated experimentation, inquiry, and adaptation.

In our analysis, reflection is not treated as an individual or introspective act. Instead, it is conceptualized as a shared process of negotiating meaning and a professional stance in response to the scenarios presented in the vignette. It is in these reflective acts that students articulate and shape their understanding of professional responsibility, ethics, and technological mediation as a part of practice. To understand how such reflection unfolds socially, we draw on Trede and Jackson's (2019) concept of *huddles*: informal, practice-based spaces in which professionals engage in shared inquiry, deliberation, and mutual support. We treat the focus-group setting as a huddle-like space that enables dialogic exchanges oriented toward shared professional reasoning. Drawing on Schön's (2017) concept of reflection and Trede and Jackson's (2019) notion of huddles, we conceptualize professional judgment as a dynamic, ethically oriented, and socially negotiated capacity that emerges through collaborative inquiry in complex situations.

While reflection and collaboration are central elements of judgment, we also emphasize technology's mediating role. We conceptualize the GenAI-generated vignette as a *boundary object* (Star and Griesemer 1989), an artifact that maintains enough coherence to be shared, but enough interpretive flexibility to be understood and used differently by participants within or across professional domains. Even in homogeneous groups, students bring varied understandings, priorities, and professional sensibilities to the table. The vignette, with its narrative openness and ethical ambiguity, provides a shared stimulus for reflection while allowing multiple interpretations to co-exist. It acts as a space for collaborative inquiry, enabling participants to surface, negotiate, and refine their perspectives in relation to both the scenario and their emerging profession-

al identities. In this way, the vignette not only serves as a tool for coordination or discussion but also activates key *boundary learning mechanisms* (Akkerman and Baker 2011). The GenAI vignette thus aims at supporting not only reflective engagement but also the *learning potential* that emerges at the boundary of differing interpretations, even within a single professional domain.

Methods

This study applies a qualitative case study design (Yin 2014) to examine how pre-service social educators develop professional judgment through collaborative reflection on an ethically complex, GenAI-generated video vignette. The case is positioned as part of a broader research initiative on the development of reflective and ethically grounded professional agency in digitally mediated learning environments. Methodologically, we treat the vignette as a designed, mediating artifact and examine its affordances for scaffolding collective reflection.

The participating students were enrolled in the Social Education program at a Danish university college and were in their third semester, specializing in school and leisure pedagogy. At this point in their studies, they had received foundational instruction in pedagogy, ethics, and professional judgment, making them well-positioned to engage with complex practice-oriented dilemmas. Participation was embedded in an existing course module, ensuring alignment with curricular goals and situating the vignette within an authentic learning activity.

Development of the GenAI vignette

The research team developed the vignette collaboratively using a generative language model and a text-to-video AI technology. Initially, the team created a written prompt describing a fictional, yet realistic scenario rooted in the everyday practices of social educators. This script was then transformed into a short video using a multimodal GenAI platform capable of producing synthetic visuals, voiceovers, and dialogue.

The vignette centered on a newly developed AI-based app designed to assist children with autism in recognizing emotions during social interactions. The app utilized facial recognition and real-time feedback to guide the child's interpretation of emotional

expressions, features that introduced both pedagogical possibilities and ethical dilemmas. The scenario was designed to reflect core tensions in social educators' work, especially those specializing in school and leisure pedagogy; rather than presenting a problem with a clear resolution, the vignette combined ambiguity, emotional salience, and professional recognizability. This was done to stimulus situated judgment and collaborative reflection. The design process involved multiple rounds of iterative prompting and evaluation to ensure authenticity and affective resonance.

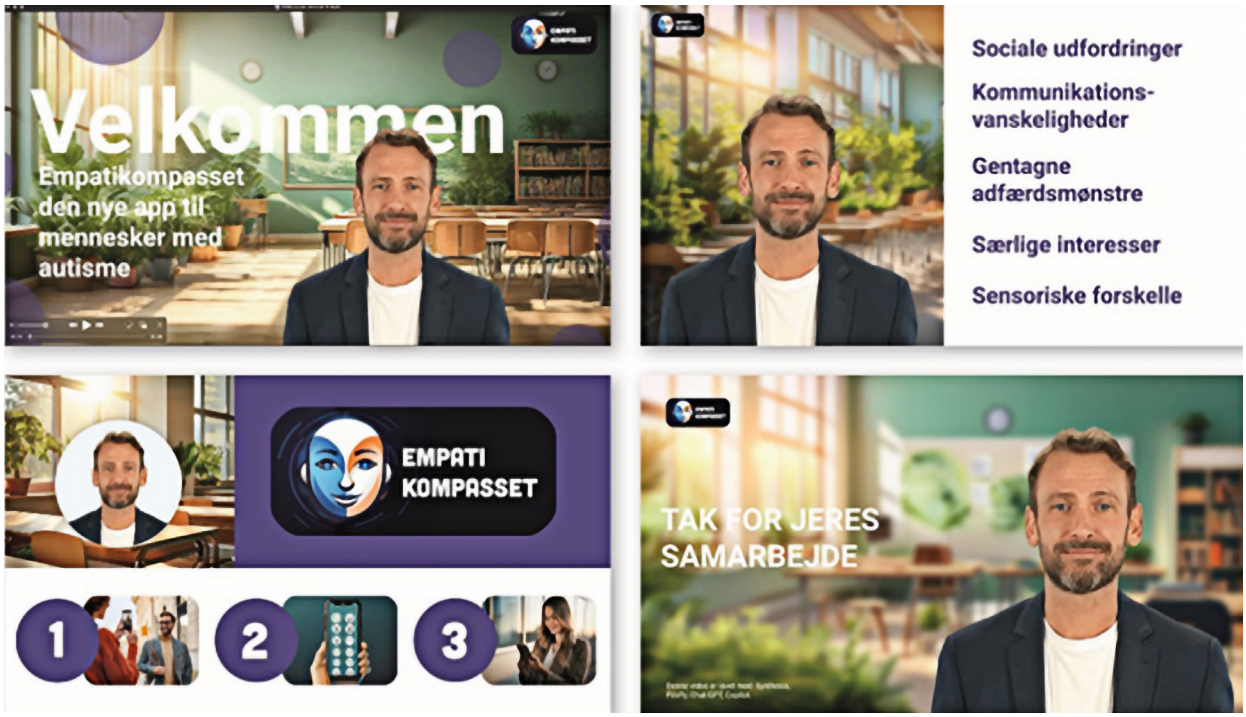

Figure 1. Image of the GenAI vignette

Data collection

Data were collected from two complementary sources: written group reflections andœ a focus group interview. All 23 pre-service social educators (SE) enrolled in the Social Education program School and leisure specialization, 3rd semester, were invited to participate. Three pre-service SEs agreed to participate in a focus group interview, while the remaining were assigned to reflection groups. These groups collaboratively produced written responses to a

shared set of reflection questions (Appendix) which also structured the focus-group dialogue. This parallel design ensured coherence across data sources and enabled a comparative analysis of individual and collaborative meaning-making processes. The focus group session was audio-recorded and transcribed. All participants' names were changed to preserve anonymity. Table 1 provides an overview of participants across data types and programs.

Program	Focus Group Interview	Reflection Groups	Total Students	Semester
Social Education	3 students	6 groups (3–4 students per group)	23	3rd

Table 1. Overview of Data Collection

Ethical considerations

All participants received written and verbal information about the study and provided informed consent prior to participation (Creswell and Creswell 2018). Participation was voluntary, and the pre-service SEs were informed that they could withdraw at any time. Data were anonymized during transcription, and all identifying details, including names, were altered to protect participant anonymity. Ethical approval was obtained through internal university procedures, and all research activities were conducted in compliance with institutional ethics protocols and GDPR regulations.

Analytical strategy

The analysis was grounded in Schön's (2017) theory of professional reflection and judgment. We explored how pre-service SEs responded to the vignette as a boundary-object artifact that challenged established patterns of thought and action, prompting either *reflection-in-action* (emergent within the group dialogue) or *reflection-on-action* (acerticulated in written or retrospective accounts). Reflection was understood not as introspection, but as a collaborative inquiry into the ethical, relational, and technological dilemmas emerging from the scenario. Consistent with our methodological focus, we analyzed how specific affordances of the Gen-AI vignette appeared to scaffold these reflective moves.

To better understand how such reflection unfolded socially, we drew on Akkerman and Bakker's (2011) framework of *boundary learning mechanisms*. These include:

- **Identification** – how pre-service SEs articulated their professional stance and clarified disciplinary boundaries.
- **Reflection** – how engagement with peers and the vignette allowed for comparison, questioning, and reconsideration of their assumptions.
- **Coordination** – how pre-services develop shared language and strategies to address the dilemma.
- **Transformation** – how new understandings emerge through interaction, sometimes resulting in the repositioning or rethinking of professional practice.

Operationally, we applied these mechanisms as interpretive lenses across both data sources (focus-group transcript and written group reflections), treating speaking turns and paragraph segments as units of analysis. Pattern-matching (Yin 2014) guided cross-case comparison between mechanisms and observed interactional moves. We traced how pre-service SEs' understanding of professional judgment, ethics, and technology evolved through engagement with the vignette and one another.

Selected transcripts were independently reviewed by a second researcher to support analytical credibility and ensure interpretive consistency. While the study is limited to a single data collection point, it captured situated, collaborative reflection triggered by a GenAI-mediated scenario. This highlights how shared artefacts can structure and support professional learning in higher education.

Findings

In this section, we analyze how pre-service SEs engaged with a GenAI-generated vignette and how their collaborative reflection unfolded through the four boundary learning mechanisms identified by Akkerman and Bakker (2011). These mechanisms offer a deductive lens for tracing how professional judgment develops when pre-service SEs encounter ethically complex, technology-mediated scenarios. Throughout the analysis, we also draw on Schön's (2017)

concept of reflection-in-action to highlight the situated and dynamic character of the pre-service SEs' meaning-making.

Identification: Establishing professional values and boundaries.

The first analytical theme concerns how pre-service SEs articulated their professional stance and pedagogical boundaries. The vignette's ethically ambiguous, technology-mediated dilemma provoked many pre-service SEs to respond with strong normative assessments. These assessments reflect identification as a process through which learners clarify who they are and what they stand for professionally. Early in the discussion, several participants expressed ethical discomfort with the technological mediation itself. They questioned whether reliance on digital tools might reduce spontaneity or obscure individual differences. Rather than treating these concerns as opinions about AI, we interpret them as boundary-setting moves that clarified the values underlying their professional reasoning. These tensions were not merely obstacles but productive triggers for reflection, as the ethical frictions embedded in the vignette compelled participants to articulate and negotiate their professional values.

Several pre-service SEs immediately positioned themselves as protectors of relational pedagogy, emphasizing that technology should not replace human interaction. One group wrote: "We think it's a bad idea to introduce something like this, both because it can take away the personal aspect of the relationship..." (Reflection assignment, pre-service SE, Group 1). Others invoked professional responsibility and ethical concern: "We must use our professional judgment to assess whether this type of technology is ethically appropriate for the target group." (Reflection assignment, pre-service SE, Group 2). Similarly, another pre-service SE emphasized the irreplaceable role of interpersonal engagement: "I also just think that when everything is done through screens [...] I just believe that having human contact is better." (Pre-service SE, interview, Susan). These reflections express discomfort with the app's premise and the broader trend of digital mediation in pedagogical settings. Theoretically, these reactions map closely to Akkerman and Bakker's concept of identification, where professional boundaries are drawn and defended. In Schön's terms, these early reflections represent

practitioners' response to value-laden indeterminacy, a necessary precursor to deeper inquiry.

Coordination: Negotiating shared meaning within the group.

Despite these strong initial identifications, the collaborative setting created space for pre-service SEs to explore tensions rather than resolve them. Coordination unfolded through mutual recognition of ambiguity and difference, often in response to peers' perspectives. The collaborative setting encouraged pre-service SEs to reflect on how professional dilemmas can be perceived differently. In one focus group, a pre-service SE remarked: "I think it also shows how differently people interpret the situations they observe." (Pre-service SE, interview, Susan). Rather than striving for consensus, the group acknowledged interpretive variation as a condition of learning. In one group reflection, differing viewpoints emerged across pre-service SEs' responses, indicating that the presence of disagreement allowed for multiple interpretations and encouraged a more nuanced exploration of the vignette's dilemmas (Reflection assignment, pre-service SE, Group 2). Here, the GenAI vignette functioned as a boundary object that sustained joint attention while permitting divergent readings, precisely the condition under which coordination (shared language, provisional strategies) could develop. Pre-service SEs also recognized that interpretation is shaped by individual experience: "I also think this shows how differently people interpret the situations they observe." (Pre-service SE, interview, Susan). The vignette functioned as a boundary object (Star & Griesemer, 1989), enabling both shared focus and diverse interpretation.

Reflection: Reconsidering assumptions and exploring alternatives

Overall, the results suggest that the GenAI vignette functioned not only as a didactic stimulus but as a boundary object (Star and Griesemer, 1989) that promoted both engagement and professional negotiation among pre-service SEs. Here, the boundary object is used as a pedagogical artifact that maintains shared reference while inviting divergent interpretations, precisely the condition that fosters collaborative reflection. Its narrative ambiguity and ethical complexity created space for collaborative meaning-making and

triggered pre-service SEs to seriously consider the interplay between technology and pedagogical practice. For some, this process led to a reaffirmation of core professional commitments. As one pre-service SE noted: "Technology must not replace professional pedagogical work" (Pre-service SE, interview, Jill). The process also triggered new forms of reflection, including reimagined uses of technology consistent with their values: "If social educators also uses the app, you can help support its use and help understand the emotions" (Reflection assignment, pre-service SE, group 3). Rather than settling for binary attitudes of acceptance or rejection, many pre-service SEs explored the conditions under which such a tool could become pedagogically meaningful. Through dialogue and discussion, the vignette helped them bring professional concerns to light. It also helped them test alternative frameworks and experiment with what Schön (2017) calls a reflective conversation about the situation.

Across the focus groups and written reflections on action, professional judgment was not presented as a static property, but as something emergent, social, and situated. It was negotiated within a shared space where emotional reactions, practical experiences, theoretical knowledge, and ethical commitments came into play. Through these interactions, the GenAI vignette supported shifts from initial stances toward context-dependent reasoning about practice.

Reflection emerged not as individual introspection, but as a collective and affectively rich process. One group reconsidered earlier skepticism: "We talked a lot about how this might work for some, especially in training situations. I hadn't really considered that before" (Pre-service SE, interview, Jill). Such comments reveal the beginnings of reflective flexibility. Another pre-service SE added a practical pedagogical scenario: "If you are prepared as an SE, you can use the app to practice with a child with autism" (Pre-service SE, interview, Marc). One comparison to analog learning aids further illustrated this reframing: "It's a bit like, you could easily create a kind of memory card game with them" (Pre-service SE, interview Jill). Another quote expands the lens beyond autism: "Just because you have autism doesn't mean you're unable to understand emotions. [...] All children need to learn about that" (Pre-service SE, in-

terview, Jill). Taken together, these shifts exemplify reflection as contrastive, negotiated, and scaffolded by a shared artefact.

Transformation: Reimagining technology's role in practice

While identification and reflection marked early phases of the learning process, several pre-service SE responses demonstrated transformation, where participants reconceptualized assumptions or envisioned alternative pedagogical strategies. One group that initially rejected the app wrote: "It's a bad idea […] because it takes away the personal aspect of relationships" (Reflection, Group 1). Later, however, the same group suggested: "You could use it as a training tool […] so they can learn to read facial expressions" (Reflection, Group 1). We interpret this shift as design-oriented rethinking consistent with Schön's account of adaptive professional reasoning.

Pre-service SEs also adapted the app concept to fit relational pedagogy better: "The app could become a Google speaker instead of a phone, so it doesn't interrupt the conversation" (Reflection, Group 3). Others challenged diagnostic assumptions: "Maybe it's our fault that the child will not learn about emotions?" (Interview, Jill). These examples indicate a growing epistemic agency and moral reflexivity. Crucially, such transformations were socially co-constructed. As one group reflected, "It was more legitimate to disagree [...] and find solutions" (Reflection, Group 2), while another emphasized, "We had a good discussion [...] and all came up with relevant ideas" (Reflection, Group 1). Methodologically, we read these outcomes as boundary-learning effects: the vignette's shared-yet-flexible form sustained disagreement productively, enabling participants to reconfigure practices and roles in dialogue.

Concluding remarks

This study reveals how GenAI-generated video vignettes can serve as valuable pedagogical tools in professional education, particularly when ethical complexity and technological mediation are brought into focus. The findings illustrate that collaborative reflection, scaffolded by such vignettes, enables pre-service social educators to move from initial moral positioning to deeper ethical deliberation and design-oriented rethinking of their practice. Importantly, professional judgment did not emerge as a fixed or in-

dividual trait but as a socially constructed, dynamic, and situated capacity, forged in dialogue with others.

This study confirms earlier concerns raised in the literature about the limitations of individual reflection tasks, often criticized for their superficiality or instrumentalism (Brown et al. 2013; de la Croix and Veen, 2018). Our findings, however, are in line with those of Iiskala et al. (2011), who emphasize the value of socially situated reflection in collective contexts. Moreover, we extend vignette methodology by specifying how GenAI video vignettes introduce emotionally rich, ethically ambiguous, and context-sensitive prompts that extend beyond traditional text-based forms (Jenkins et al. 2020; Demetriou 2023). Concretely, we reveal how these artefacts function simultaneously as boundary objects that support a shared focus despite divergent readings and as affective triggers that invite engagement, thereby scaffolding collective reflection and shared professional reasoning.

Our study also adds nuance to existing collaborative reflection research. While earlier work stressed deliberation and co-construction (Finlay and Gough, 2003; Trede and Jackson, 2019), our use of boundary learning theory illustrates the learning potential not just in moments of agreement but in the productive frictions that arise from disagreement and uncertainty. This highlights the importance of designing learning environments that do not prematurely resolve complexity. Instead, they allow pre-service SEs to dwell in ambiguity and work through tensions collectively.

Finally, this study advances methodological innovation in professional education by showing how GenAI-generated video vignettes can be used not as answers or shortcuts but as provocations that spark ethical reasoning, collective inquiry, and pedagogical imagination. It also contributes theoretically by integrating Schön's account of reflection in action with boundary learning to explain how shared artefacts scaffold the emergence of professional judgment. Practically, GenAI vignettes should be designed for ethical ambiguity, recognizability, and affective resonance, and facilitated in ways that keep multiple interpretations in play rather than push for early consensus. Future research could explore how different forms of GenAI vignettes (e.g., interactive or multimodal) shape reflection across diverse professional settings, and whether such approaches foster lasting shifts in professional judgment over time.

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Appendix

Question sheet for pre-service social educators.

The Danish Autism Association is developing an app called *The Empathy Compass*. What considerations would you, as professional educators, make in relation to using this app as part of your pedagogical practice?

Requirements set by the association for the app:

- It should help autism patients decode others' facial expressions and body language.
- It should provide tips for social interaction and communication based on the photos taken with the app.
- It must comply with the current legislation.
- It should use AI to perform its functions.

Explore the case further:

Spend 5–10 minutes researching to gain a proper understanding of the case before beginning your discussion. (Link for inspiration).

- https://www.sundhed.dk/borger/patienthaandbogen/psyke-hos-boern/sygdomme/udviklingsforstyrrelser/autismespek-trumforstyrrelser/
- https://www.autismeforeningen.dk/news/nyheder-2020/in-ternational-autismedag-fordomme-og-fakta-om-autisme/
- https://digst.dk/strategier/strategi-for-kunstig-intelligens/
- Autism (Autism Spectrum Disorder) | Psykiatrifonden
- Emotionary by Funny Feelings
- Emotions from I Can Do Apps
- FaceReader Software | FR-PROJECT, FR-ACTIONUNIT, FR-SOFTWARE | BIOPAC

See the discussion questions on the next page.

Question 1:
Begin by discussing what you should pay attention to if such an app were developed, based on your professional and pedagogical knowledge. *(Explore and understand the case).*

- How might this app support participation opportunities for people with autism (in everyday life and in society), and how could the concept be used by professional educators in their work with the target group?

Question 2:
Next, discuss how this app could become a useful solution for autism patients. *(Explore and understand professional work processes)*

- What possibilities for action do you think an app like *The Empathy Compass* could offer you as educators working with this group?
- Are you familiar with other pedagogical tools used in similar situations?

Question 3:
Discuss the advantages and disadvantages of such technology in your practice. *(Requirements for a successful solution).*

- What wishes or requirements would you, as educators, have for such an app? What should it do?
- How would you, as educators, support citizens in using such an application?
- For whom was the application developed — the individual user or the institution?

Question 4:
What ethical considerations would you make if you implemented and used such an app? *(Ethics and professionalism)*

- What potential issues and/or conflicts can you identify from using such an app in social contexts? (e.g., legislation, consent, social codes and boundaries, the use of collected data, and other ethical concerns)

Question 5:

Imagine that you are implementing this app in your workplace — what professional considerations would you make? *(Ethics and technology)*

- Discuss the advantages and disadvantages of using this app in pedagogical practice.
- What ethical challenges can you identify as professional educators? For example, what potential issues might arise for the user when using the app, and what challenges could it create for the people the user interacts with?
- What kinds of challenges or conflicts might you anticipate arising in your encounters with children, young people, or adults with autism when working with *The Empathy Compass*?