*Corresponding Author's Email: niklas.ferdinand.carlsson@liu.se
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Beyond Information Literacy: Librarians as Pedagogical Designers in Higher Education

Niklas Ferdinand Carlsson
Linköping University, Sweden

Abstract

Academic libraries are increasingly moving from service-oriented support to active pedagogical partnership in higher education. This paper presents a library-based makerspace initiative as a learning partner and introduces two complementary artefacts: (1) the Makerspace Pedagogical Framework (MPF), a constructively aligned conceptual lens integrating Education 4.0, Digital Literacy (DL), and Information Literacy (IL); and (2) a Collaborative Design Protocol (CDP), a repeatable co-design workflow that operationalises library–faculty collaboration from initiation and planning to implementation, evaluation, and iteration. The frameworks are proposed as resources that may inform future makerspace-supported collaborations more broadly. Empirical evidence reported in this paper derives from repeated nursing-programme workshop implementations (the primary evaluative case). Two implemented workshops are analysed: an immersive VR activity structured around inquiry and embodied experience, and a gamified escape-room workshop designed for time-bounded collaboration and evidence-based problem solving. Evidence is synthesised across nursing iterations using post-workshop surveys and qualitative reflections/field notes, while additional implementations in humanities/teacher education and engineering are referenced only to demonstrate transferability of the MPF/CDP approach. Across the nursing workshops, students reported strong engagement and perceived relevance in technology-enhanced formats but also expressed a need for clearer scaffolds that support consolidation and make learning progress visible during exploratory tasks. To illustrate further transferability within nursing, the paper also presents a planned (non-empirical) design exemplar in which students critically evaluate 18th-century remedy texts against contemporary research evidence and social-media health claims. The paper argues that libraries can act as co-educators by aligning makerspace technologies with course ILOs and assessment through an explicit, repeatable co-design protocol, enabling local adaptation while maintaining methodological transparency.

Keywords: Education 4.0; information literacy; makerspaces; academic libraries; nursing education

1. Introduction

Higher education faces a twofold mandate: respond pedagogically to learners who are already socialized in digitally mediated environments and prepare graduates for technology-rich workplaces that demand both domain knowledge and transferable socio-cognitive competencies (critical thinking, collaboration, adaptability). As contextual background for contemporary student expectations, research on Generation Z in professional education underscores the growing relevance of interactive, technology-mediated learning and structured collaboration (Priyanshu et al., 2025; Sundareswaran et al., 2024). Education 4.0 captures this broader transition by emphasizing learner-centred, technology-enhanced, and competency-driven education: shifting curricula from content-heavy transmission toward adaptive, experiential, and assessment-aligned learning that makes deliberate use of immersive technologies such as virtual reality (VR) and AI (Biggs, 1996; Biggs & Tang, 2011; Huk, 2021; Mukul & Büyüközkan, 2023; Ramírez-Montoya et al., 2021; World Economic Forum, 2023).

Academic libraries are uniquely placed to support this transformation. Beyond traditional roles in collection care and information instruction, libraries can act as interdisciplinary access points that combine expertise in information practices with physical and digital infrastructures for making and experimentation. At one university library, this institutional potential is realised through a library-based makerspace initiative that combines a broad toolset (3D-printers, VR, audio/video equipment, lending services) with a pedagogical programme staffed by makerspace personnel and trained student workers. The makerspace functions simultaneously as a library of tools, a site for student co-creation, and an active curricular partner.

LIS scholarship has increasingly framed academic librarians not only as service providers or information-skills instructors, but as educational actors whose work spans teaching, instructional design, advocacy, and partnership across the curriculum (Association of College and Research Libraries [ACRL], 2017; Corrall & Jolly, 2019). Corrall and Jolly (2019) argue that while libraries have long contributed to student learning, the role of librarians as teachers remains both important and contested within higher education. ACRL's (2017) professional guidance likewise conceptualizes the "teaching librarian" as occupying overlapping roles such as teacher, teaching partner, instructional designer, coordinator, and advocate, positioning librarians as contributors to course and curriculum design rather than only to isolated instructional sessions. Recent empirical work further suggests that librarians' pedagogical expertise is not always fully recognized by faculty, particularly when their contributions are reduced to one-shot instruction (Becksford, 2022). At the same time, emerging models of faculty development and assignment co-design point toward a more integrated and sustainable role for librarians in shaping disciplinary learning (Fundator et al., 2025).

Parallel to this shift in instructional identity, LIS research on academic library makerspaces has increasingly moved beyond describing tools and facilities toward understanding makerspaces as pedagogical and cross-disciplinary learning environments (Curry, 2023). In a higher education library makerspace case study, Curry (2023) argues that academic librarians' relational agency is central in bringing together students, academics, and technologies within inclusive maker-learning systems. From this perspective, library makerspaces are not simply sites of access to equipment, but environments in which embodied, collaborative, and reflective learning can be scaffolded through librarian facilitation (Curry, 2023). This is especially relevant to the present study, as it supports a view of the library makerspace as a curricular partner capable of aligning technological experimentation with broader educational, ethical, and disciplinary aims (Curry, 2023). This positioning also connects library-based pedagogical development to learning design and co-design scholarship, which frames curriculum development as a collaborative, iterative practice involving multiple forms of expertise across professional boundaries. For libraries, this perspective strengthens the case for librarians as pedagogical design partners in non-STEM as well as STEM and health contexts, particularly where constructive alignment must accommodate interpretive, reflective, and practice-based forms of assessment (Laurillard, 2012; Bovill, 2020).

This paper introduces the Makerspace Pedagogical Framework (MPF), a conceptual framework that emerged from iterative practice in the makerspace. The MPF integrates three mutually reinforcing lenses, Education 4.0, Digital Literacy (DL), and Information Literacy (IL), and uses constructive alignment as the organising principle: intended learning outcomes (ILOs), learning activities, and assessment are explicitly linked so that immersive and hands-on tasks serve well-defined course goals. To support implementation, the makerspace also uses a Collaborative Design Protocol (CDP): a repeatable, co-designed workflow for integrating makerspace activities into credit-bearing curricula (initiation, planning, design, implementation, and evaluation/iteration). Taken together, the MPF specifies the pedagogical logic of “what and why,” while the CDP specifies the collaborative process of “how.”

The MPF is proposed as a framework for future makerspace-supported activities across several disciplinary contexts, including VR clinical simulations and escape-room scenarios in health sciences, multimedia production and critical source evaluation in humanities and teacher education, and iterative 3D-modelling/3D-printing tasks in engineering. The empirical results presented in this paper, however, are based solely on data from repeated implementations in the nursing workshops; the other disciplinary contexts are referenced to demonstrate adaptability rather than analysed as empirical material here.

The aims of the paper are threefold: (1) to present the MPF as a constructively aligned conceptual lens integrating Education 4.0, DL, and IL; (2) to describe the CDP as a repeatable co-design process for embedding the makerspace into credit-bearing curricula; and (3) to report empirical evidence from repeated nursing-workshop implementations and discuss implications for curriculum design and the evolving instructional role of academic libraries. Evidence is synthesised across nursing workshop iterations; implementations in other disciplines are included to demonstrate transferability rather than to provide empirical results and will be evaluated in future work. Building on this institutional positioning, the pedagogical framework and collaborative design process presented in this paper were developed through collaboration with the nursing programme and are proposed as resources that may inform future makerspace-supported collaborations.

1.1 Fundamentals and origins of the makerspace

The makerspace’s origins can be traced to an institutional exploration of Digital Humanities as a conceptual and practical entry-point. Digital Humanities offered a compelling frame precisely because it foregrounds technological methods in disciplinary contexts that historically had lower levels of tech integration. By positioning digital tools as legitimate scholarly and pedagogical instruments in the humanities, the library found a conceptual anchor for broader institutional experimentation. The initial development pathway bifurcated into two complementary strands:

1. Digital Lab: oriented toward research support and advanced data workflows: programming assistance, digital visualization, 3D/VR-enabled research outputs, and support for faculty and postgraduate researchers needing sophisticated tools for data processing and representation.

2. The makerspace (makerspace): a student-facing, accessible workshop designed for iterative, creative practice across digital and physical media. The makerspace prioritizes low barrier-to-entry activities (multimedia, prototyping, VR, basic 3D printing) while maintaining connections to advanced lab resources where needed.

This dual configuration acknowledged differing user needs, research-grade vs. student-centred learning, and allowed the library to serve as both a research enabler and an instructional laboratory. The makerspace became a locus for experiments in pedagogy: how might hands-on, technology-enhanced activities facilitate deeper engagement with disciplinary content while concurrently developing broader literacies?

Embedded in the makerspace's early development was a pedagogical orientation that emphasized structured learning progression. From the outset, the makerspace activities were conceived around a simple scaffolding arc, *exploration, collaboration, reflection*, which supports low-threshold entry, peer-supported meaning-making, and guided consolidation. This scaffolding logic later became a natural foundation for how the makerspace designs learning activities within curricular collaborations.

1.2 Institutional context

The makerspace is a pedagogical service function embedded in the university library. It operates as a student-centred makerspace that combines a lending and production infrastructure (3D printers, VR headsets, cameras, microphones, lighting, editing suites, etc.) with an educational programme delivered by a mix of the makerspace staff and student workers. Its institutional positioning in the library creates a unique interdisciplinary access point: The makerspace acts both as a repository of tools and as an active learning partner to faculty, enabling curricular integration across faculties. The makerspace ethos emphasizes co-creation, accessibility, and peer exchange, and the unit deliberately collaborates with course teams to embed activities into established course designs.

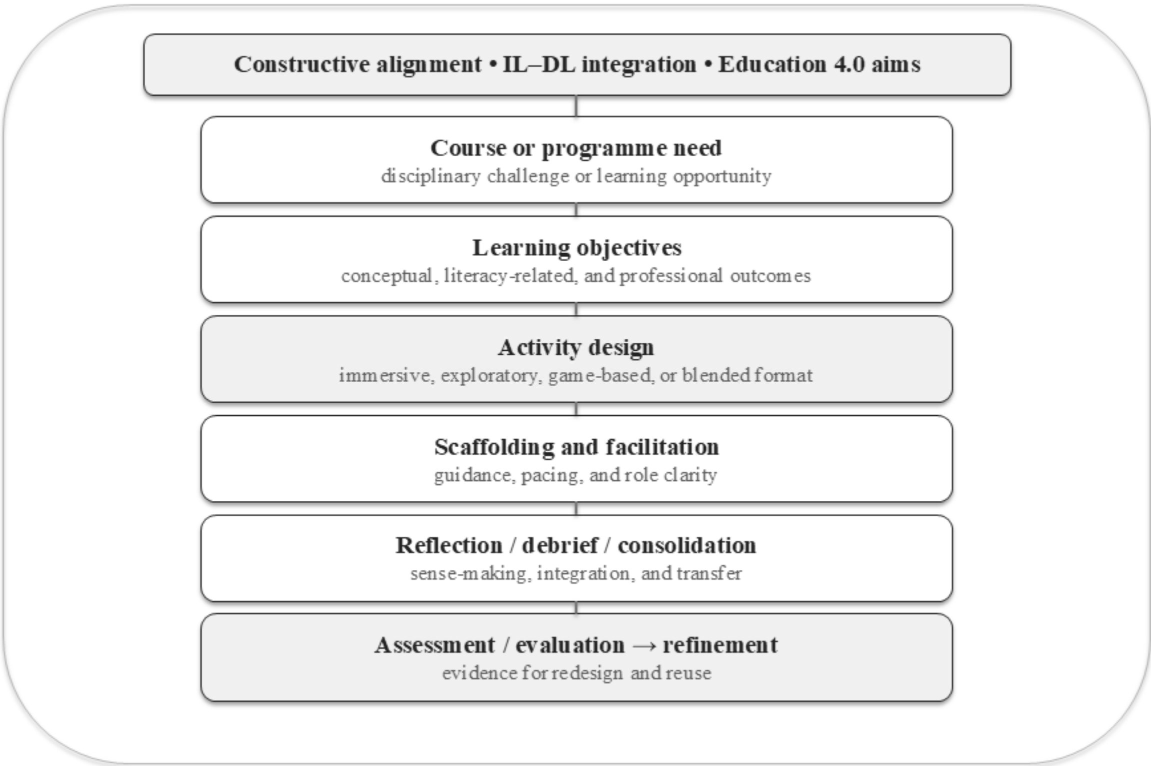
2. Materials and methods

This study describes the design, delivery and iterative refinement of makerspace–integrated learning activities grounded in a combined pedagogical framework (MPF: Education 4.0, DL, IL) and constructively aligned with course learning goals. Below I present the theoretical framing (MPF), the operational model (CDP), pedagogical practices, cross-disciplinary adaptations, and the evaluation strategy that together constitute the method used to design and study makerspace interventions. Together, these components specify how makerspace activities are systematically designed, aligned, and implemented in curriculum-facing contexts.

2.1 The makerspace pedagogical framework: conceptual lenses and constructive alignment

The MPF synthesizes three integrated lenses: Education 4.0, DL and IL. These are treated not as separate strands but as mutually reinforcing dimensions: DL supplies technical and production-related competencies (e.g., 3D-modelling, audio/video editing, VR operation), IL supplies critical evaluation and information-handling competencies (locating, evaluating, using sources), and Education 4.0 provides the learner-centred, technology-enhanced philosophy that orients the overall design toward adaptability, creativity and future-ready competencies. Constructive alignment (Biggs, 1996; Biggs & Tang, 2011) is adopted as the organising curriculum principle: ILOs, makerspace learning activities, and assessment practices are explicitly aligned so that immersive tools and hands-on tasks serve clearly identified course goals (e.g., critical reflection, applied problem-solving, professional practice). While constructive alignment is often foregrounded in STEM and health education, its emphasis on transparency between outcomes, activities, and assessment is equally applicable to humanities- and practice-based disciplines, where learning outcomes may foreground interpretation, judgement, reflective synthesis, and source-critical reasoning rather than procedural mastery. Pedagogical concepts operationalised in practice include experiential learning, collaborative learning, and peer-to-peer dynamics. The MPF is summarised visually in Fig. 1 to clarify the minimal pedagogical components that remain stable across makerspace-supported intervention formats while preserving coherence between learning goals, activity design, facilitation, reflection, and evaluation.

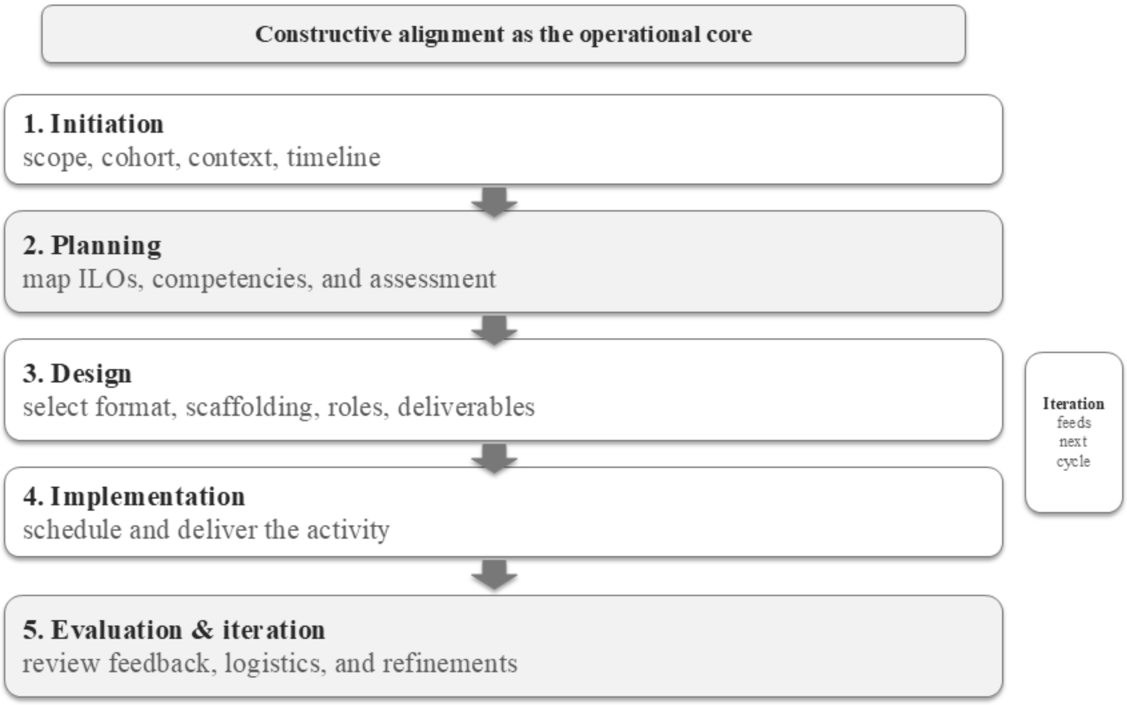
Figure 1: Makerspace Pedagogical Framework (MPF). The MPF integrates Education 4.0, Digital Literacy, and Information Literacy through constructive alignment of learning outcomes, activities, facilitation, reflection, and evaluation.



2.2 Collaborative design protocol: the operational model

The CDP operationalises collaboration between the makerspace and course teams by translating the MPF into aligned, assessable learning activities through a structured co-design workflow. While the CDP provides a comprehensive workflow for in-depth curricular collaborations, not all makerspace engagements require the full protocol; in some cases, the makerspace contributes through short, standalone workshops that introduce tools, concepts, or resources without full integration into course design. Fig. 2 presents the CDP as an iterative co-design workflow through which makerspace and course teams translate the MPF into aligned, assessable learning activities.

Figure 2: Collaborative Design Protocol (CDP). The CDP operationalises the MPF through an iterative co-design process linking initiation, planning, design, implementation, evaluation, and refinement.



The CDP is centred on constructive alignment:

1. Initiation

   - Collaboration may be proposed by makerspace staff or by faculty/course teams.
   - Partners agree on scope, target cohort, course context and timeline.
   - A short project brief is produced (objectives, constraints, preliminary equipment needs).

2. Planning: mapping course learning goals

   - Makerspace staff and course teachers jointly review the course's ILOs and assessments.
   - During planning, intended learning outcomes are mapped to makerspace activities, targeted competencies (DL/IL/Education 4.0), and appropriate

assessment formats. This practical application of constructive alignment helps ensure that each design choice serves a clearly defined learning purpose.

- Planning artifacts include session outlines, risk/ethical checks (e.g. VR suitability, data protection), and an equipment list.

3. Design: selecting pedagogical elements

    - Activity format (e.g. workshop, VR scenario, escape-room, drop-in lab) is selected to suit ILOs and the disciplinary context.

    - Learning tasks are scripted to follow agreed scaffolding: exploration, collaboration, reflection.

    - Roles are assigned (course teacher, makerspace facilitator, student workers if applicable), and student deliverables/assessment criteria are drafted.

4. Implementation: delivery

    - Sessions are scheduled into the course timeline and delivered either co-facilitated with course teachers or by makerspace personnel as agreed.

    - Student groups are organised to support group-based experiential learning. Workshops emphasise hands-on engagement; while peer-to-peer assistance is present, facilitation is structured so that experiential learning remains the primary pedagogy.

5. Evaluation & iteration

    - After delivery, partners perform a structured debrief that reviews participant feedback, teacher observations and practical/logistical issues.

    - Iterative changes (content, timing, scaffolding, equipment) are recorded and implemented in subsequent runs.

    - The evaluation phase seeds the next collaborative design cycle, making iteration an integral methodological step rather than a post-hoc activity.

2.3 Pedagogical practices and scaffolding

Makerspace activities are intentionally diverse but follow common scaffolding principles:

Formats used:

- Short, focused workshops (1–3 hours) integrating a brief conceptual framing with immediate hands-on practice.
- Extended labs and project-based integrations across multiple sessions.
- Drop-in peer support and student-led sessions run by student workers.

2.3.1 Scaffolding principle

Each intervention follows an explicit sequence: exploration (safe exposure and sense-making), collaboration (group problem solving, negotiation of roles), reflection (structured debriefs, reflective logs or assessment tasks). Reflection is guided to link practical activity back to IL and DL principles and to the course ILOs. In this context, scaffolding means providing a structured underlying learning arc that supports students' progression; ensuring that the purpose, sequence, and expectations of each activity are clear and meaningful in practice.

2.3.2 Positioning of students

Students are framed as active co-creators (not passive recipients). In the makerspace ecosystem, this co-creation takes two forms:

1. Makerspace culture (structural peer-to-peer): informal, ongoing peer support and student worker–led guidance that sustains daily operations and drop-in learning.
2. Workshop context (structured experiential collaboration): group tasks are facilitator-designed and teacher-aligned; peer learning occurs through collaborative problem solving rather than open-ended student teaching. Methodologically, I distinguish between two learning dynamics: peer-to-peer learning is treated as a structural feature of the makerspace ecosystem, while the workshops are designed around structured experiential collaboration as the primary pedagogical strategy.

2.3.3 Cross-disciplinary adaptation

The method is intentionally flexible to fit disciplinary needs. Examples of discipline-tailored implementations include:

- Health sciences / Nursing: VR clinical scenarios, escape-room puzzle boxes and evidence-based analysis of old folk remedies that simulate and nuance patient states, followed by data collection exercises and reflective analysis tied to clinical decision-making ILOs.

- Humanities / Teacher education: e.g. multimedia production workshops (audio/video) that foreground critical source evaluation and digital storytelling tied to pedagogical ILOs.

- Engineering: e.g. iterative 3D-modelling and 3D-printing tasks that emphasize prototyping, design thinking and applied problem solving linked to technical ILOs.

2.3.4 Evaluation strategy and data collection

In this paper, reported empirical data are drawn from the nursing workshops, including the VR and escape-room iterations. Evaluation was embedded into the design process rather than treated as an afterthought, serving both formative improvement and summative evidence gathering. To make the constructive-alignment process transparent, Table 1 provides a concise exemplar of how intended learning outcomes, makerspace activities, IL/DL competencies, and assessment or reflection were aligned during workshop planning.

Table 1: Example constructive-alignment matrix used during workshop planning

Course ILO	Makerspace activity	IL/DL focus	Assessment/reflection
Apply evidence-based reasoning in clinical contexts	Escape-room puzzle stations using medical cases	IL: source evaluation and evidence appraisal; DL: database/AI-supported searching	Group debrief and short reflective justification of evidence choices

The makerspace's evaluation toolkit is mixed-methods and triangulated and may include:

Quantitative measures

• Pre/post surveys mapping self-reported DL/IL confidence and competency scales aligned to ILOs.

• Participation logs and engagement metrics (attendance, tool-usage records).

Qualitative measures

• Structured teacher/researcher observation protocols capturing behavioural indicators (collaboration quality, use of tools, problem-solving strategies).

• Student reflections (written reflective logs or guided prompts) and selected open-ended survey responses.

• Focus groups or semi-structured interviews (when appropriate) to deepen understanding of learning processes.

For the nursing implementations reported here, the empirical material consists primarily of post-workshop surveys, participation/engagement notes/logs where available, and qualitative reflections/field notes. Additional instruments (e.g., pre/post designs, interviews) are part of the broader evaluation toolkit and may be used in future iterations. The VR case draws on two post-session instruments: (1) a bespoke 7-item VR perception scale aligned with session-level learning aims (analysis, exploration, conceptual understanding, and perceived relevance), and (2) the 34-item Community of Inquiry (CoI) instrument measuring teaching, social, and cognitive presence. The CoI instrument has established validity and reliability across online, face-to-face, and immersive learning contexts. In the published VR study, internal consistency was acceptable to high (Cronbach's α ranging from 0.84 to 0.96), though estimates are constrained by the small, self-selected sample (N = 16).

2.3.5 Analytic approach

Analysis focused on identifying cross-workshop patterns relevant to the development and refinement of the MPF and CDP. Triangulation proceeded in three steps: (1) quantitative survey results were summarised to identify dominant patterns of engagement, perceived learning, and perceived relevance; (2) qualitative field notes and open-ended responses were reviewed to explain, nuance, or contextualise these patterns; and (3) convergences and divergences across data sources were discussed during post-implementation debriefs with course staff and used to inform subsequent refinements. The focus in this article is on synthesising cross-workshop patterns to inform the MPF; fine-grained analyses of individual datasets may be prepared for separate reporting.

2.3.6 Ethical and practical considerations

The activities were conducted as part of educational development and evaluation. Participation in evaluation activities was voluntary, and written informed consent was obtained from participants where individual survey responses were collected. Responses were anonymised to protect privacy and confidentiality. According to institutional guidelines, formal ethics review was not required for this type of educational research, as no sensitive personal data were collected. No compensation was provided to participants. Practical risk mitigation, including VR safety briefing, equipment hygiene, and accessibility accommodations, was included in planning documents.

2.3.7 Methodological note (replicability)

The combination of a transparent constructive-alignment process within the CDP and documented evaluation instruments allows makerspace activities to be reproduced or adapted by other library-based makerspaces. Where appropriate, session templates, alignment matrices and evaluation instruments are versioned and stored as project artefacts to support future replication and continuous improvement.

3. Results

3.1 Workshop 1. VR workshop: immersive learning for nursing education

This constructively aligned workshop integrated Education 4.0 principles with the Community of Inquiry (CoI) framework, using VR to create an experiential learning environment for first-semester nursing students. The activity was co-designed with the university library makerspace to embed DL and IL into a collaborative, inquiry-driven format (Carlsson, 2025). Students engaged in two contrasting VR scenarios, sympathetic activation via a roller coaster simulation and parasympathetic stimulation through guided meditation, while peers conducted clinical assessments (e.g., heart rate, blood pressure). These physiological data informed group analysis and reflective discussion, linking embodied experience to theoretical concepts in autonomic regulation. Teachers acted as facilitators, encouraging critical thinking and evidence-based reasoning without providing direct answers, consistent with Education 4.0’s learner-centred ethos (Biggs & Tang, 2011; World Economic Forum, 2023).

3.1.1 Quantitative results

Sixteen of 134 invited first-semester nursing students participated in the optional VR workshop (12% uptake). Participation was self-selected, reflecting both practical constraints (limited VR capacity and scheduling within a dense first-semester timetable) and students’ varying comfort with immersive technologies. The workshop was intentionally offered as an optional enrichment activity rather than a compulsory course component, which introduces selection bias toward students with a higher initial interest in immersive technologies. Consequently, findings are interpreted as exploratory and illustrative of pedagogical design affordances rather than representative of the full cohort. Full item-level analyses, scale validation, and reliability estimates for the VR instruments are reported elsewhere (Carlsson et al., 2026).

On the Community of Inquiry instrument (5-point Likert scale), overall perceptions of the learning environment were moderately positive (total mean = 3.36, SD = 0.44). Cognitive presence was rated highest (mean = 3.48, SD = 0.41), with exploration showing particularly strong scores (mean = 4.48, SD = 0.49), indicating high engagement in inquiry and sense-making. Teaching presence was rated higher for design and facilitation (both mean = 3.42, SD = 0.55) than for direct instruction (mean = 2.88, SD = 0.92), suggesting effective facilitation alongside a need for clearer instructional scaffolding. Social presence was moderate (mean = 3.26, SD = 0.60), indicating that students generally felt comfortable communicating and collaborating, although affective expression was less pronounced.

On the bespoke VR perception scale, 75%–94% of participants agreed that VR enhanced analysis, exploration, conceptual understanding, teacher support, and perceived relevance to the session.

3.1.2 Qualitative insights

Students emphasized VR's ability to bridge theory and practice, describing how embodied experiences deepened understanding of physiological processes: *"Visualization and feeling made it easier to understand."* This experiential dimension reflects Education 4.0's focus on competency-based, technology-enhanced learning and supports IL/DL development through collaborative interpretation of physiological data and evidence-seeking tasks (Mukul & Büyüközkan, 2023; Ramírez-Montoya et al., 2021). Teachers observed a shift from passive reception to active, reflective engagement, reinforcing VR's potential as a catalyst for critical thinking and inquiry-based learning (Makransky & Lilleholt, 2018).

3.1.3 Interpretation and implications

The VR workshop demonstrates how immersive technologies, when constructively aligned with pedagogical frameworks, can advance Education 4.0 goals by promoting adaptability, collaboration, and critical thinking (Biggs, 1996; Lowell & Yan, 2024). High cognitive presence scores suggest VR effectively stimulates inquiry and conceptual integration, while moderate social presence and lower ratings for direct instruction highlight areas for improvement. Importantly, the VR findings do not primarily evidence learning gains; rather, they illuminate how constructively aligned, library-facilitated immersive activities can generate strong exploratory engagement while simultaneously revealing where additional scaffolding and consolidation are required: an insight that directly informed refinement of the MPF and CDP. Future iterations should incorporate:

- Enhanced scaffolding during VR tasks to balance autonomy with clarity.

- Collaborative, emotionally resonant scenarios to strengthen social presence (Makransky et al., 2019).

- Faculty development in immersive pedagogy to ensure effective facilitation (Kumar & Gorai, 2025).

Challenges such as motion sickness and limited participation underscore the need for accessibility measures and curricular integration to normalize VR use and reduce barriers (Rebenitsch & Owen, 2016). Overall, VR offers a powerful complement to traditional methods, fostering deeper engagement and reflective learning when embedded in a coherent, outcome-driven design (Liu et al., 2023).

3.2 Workshop 2. Escape room workshop: unlocking medical knowledge

This gamified workshop operationalised the MPF by combining IL, DL, and Education 4.0 principles in a timed, station-based escape-room format. Students rotated across four 3D-printed puzzle boxes, solved evidence-based medical scenarios, and generated codes from validated answers to unlock subsequent stages. Activities explicitly required critical appraisal of sources and digital searches (AI tools, pharmacological references, scholarly databases), followed by a structured debrief linking puzzle reasoning to course ILOs.

3.2.1 Participants and instruments

Post-workshop data were collected from N = 88 respondents using a 10-item Likert instrument (1–5; 1 = strongly disagree, 5 = strongly agree). The instrument addressed general game enjoyment, perceived learning, activity organisation, perceived difficulty, format preference compared with lectures, and willingness to recommend or repeat similar activities. Items were analysed descriptively at item level and as a 10-item scale for internal consistency. The negatively worded difficulty item (Q5) was reverse-coded prior to scale-level analysis. The 10-item survey showed acceptable internal consistency for descriptive use, Cronbach's $\alpha = .75$ (N = 88). No item-level missing data were present.

3.2.2 Quantitative results

The overall mean score across all items was 3.58/5, indicating generally positive perceptions. Detailed item-level results are presented in Tab 1.

Table 2: Post-workshop survey items and mean scores (Likert scale 1–5)

Item	Question	Mean
Q1	I generally enjoy playing games (e.g., video games or board games).	3.97
Q2	The theoretical part of the course related to this workshop was easy for me to understand.	3.40
Q3	The Escape Room activity helped me improve my knowledge of the course content.	3.41

Item	Question	Mean
Q4	I thought the Escape Room activity was fun.	4.45
Q5	The Escape Room activity was too difficult.	2.41
Q6	The Escape Room activity was well organized.	4.07
Q7	I preferred this teaching format over traditional lectures.	3.65
Q8	I learned more through the Escape Room activity than through a traditional lecture.	2.73
Q9	I would recommend other students to participate in Escape Room activities (even without extra credit).	4.15
Q10	I would like more courses to include similar activities (even without extra credit).	3.88

Note. Scale: 1 = Strongly disagree, 5 = Strongly agree. Survey items adapted from López-Pernas et al. (2019). Q5 is negatively worded and is presented with its raw mean; it was reverse-coded only for scale-level reliability analysis.

3.2.3 Quantitative results (clustered analysis)

To enhance interpretive clarity, survey items were grouped into two thematic clusters reflecting (1) pedagogy and learning and (2) experience. The analysis emphasised descriptive statistics and pattern identification rather than inferential testing, due to the absence of a comparison group, the exploratory intent of the study, and its pedagogical design focus. Future controlled implementations will enable effect size estimation and hypothesis testing. The two clusters were as follows:

Cluster 1 – pedagogy & learning (Q2, Q3, Q7, Q8, Q10)

- Understanding & knowledge gains: Q2 (3.40) and Q3 (3.41) suggest moderate clarity and perceived improvement.
- Preference vs. lectures: Q7 (3.65) and Q10 (3.88) indicate positive disposition toward active, Education 4.0-aligned formats.

- Comparative learning: Q8 (2.73) falls below neutral, echoing research on cognitive load and "illusion of clarity" in lectures (Freeman et al., 2014; Loughlin, 2025). These patterns align with literature noting that active learning improves long-term retention despite lower short-term confidence (Freeman et al., 2014).

Cluster 2 – experience (Q1, Q4, Q5, Q6, Q9)

- Engagement & flow: Q4 (4.45) and Q6 (4.07) show strong enjoyment and perceived organization, consistent with flow theory and gamification principles (Cai et al., 2025; Lim & Gepp, 2026).

- Difficulty calibration: Q5 had a low raw mean (M = 2.41), indicating that students generally did not perceive the Escape Room activity as too difficult. This suggests an appropriate challenge level.

- Recommendation intent: Q9 (4.15) signals high motivational value, reinforcing Education 4.0's emphasis on learner engagement and autonomy. These findings mirror escape-room studies emphasizing intrinsic motivation and structured collaboration (Nylén-Eriksen et al., 2025).

3.2.4 Qualitative results (field notes)

Groups worked highly collaboratively, using discussion as the primary sense-making mechanism and triangulating with AI, the course book, personal notes, and open web search engines. A recurring friction point was discrepancy handling (e.g., conflicts between AI outputs and the textbook), which redirected effort toward consensus-building and source adjudication. These behaviours align with the workshop's IL/DL intentions but also reveal where targeted scaffolds could make evaluative criteria more explicit. Collaboration also amplified critical thinking, as students collectively interrogated evidence and negotiated competing claims: an outcome strongly supported in game-based learning literature (Cai et al., 2025).

3.2.5 Interpretation (thematic + observational)

The escape-room format excelled in engagement and organization (Q4, Q6, Q9) and maintained balanced difficulty (Q5). However, learning perceptions lagged (Q8), a common effect of exploratory tasks without visible consolidation (Freeman et al., 2014; Zhan et al., 2025). Field notes and thematic analysis converge on three levers for improvement:

1. Collaboration as a driver of critical thinking, already strong but needs explicit role, ILO mapping to prevent uneven participation.

2. Flow vs. cognitive load: high enjoyment can mask fragmented reasoning; micro-reflection checkpoints could surface learning during play.

3. IL/DL operationalisation: source discrepancies created authentic evaluation tasks; embedding triage heuristics and claim–evidence logs would strengthen perceived and actual learning.

These refinements aim to preserve the workshop's motivational gains while amplifying its epistemic outcomes, fully aligning with Education 4.0 principles of adaptability, collaboration, and technology-enhanced learning. Together, the VR and escape-room implementations illustrate how the MPF operationalises IL, DL, and Education 4.0 through constructively aligned, collaborative, technology-enhanced activities in the nursing programme. To further demonstrate how the same CDP can generate additional nursing-relevant formats beyond the two evaluated workshops, the next section briefly presents a planned design exemplar for a future iteration.

3.3 Design exemplar (planned; non-empirical): Medical history in practice-from folk remedies to evidence

This section is included as a design exemplar to illustrate transferability of the MPF within the nursing programme. It describes a planned workshop design that follows the same CDP and constructive-alignment logic as the evaluated nursing workshops; however, it has not yet been implemented and therefore contributes no empirical results to the present paper.

3.3.1 Workshop description (planned implementation)

The workshop is designed to align the triadic MPF, IL, DL, and Education 4.0, with course-specific learning goals that connect clinical reasoning to evidence evaluation and epistemic awareness. Its primary anchor is IL, operationalised through historical source criticism and evidence-based evaluation. DL is embedded through structured digital searching and synthesis of scholarly sources, while Education 4.0 principles are enacted through collaborative, student-active inquiry.

Students will work with excerpts from The Wise and Sensible Old Man's Remedies (18th century), analysing each remedy from two perspectives:

1) Scientific principle – Is there evidence supporting the method in current research?

2) Medical efficacy – Are the described substances (e.g., alum, wormwood) effective, harmful, or inert according to contemporary pharmacological literature?

Students will conduct independent searches using AI tools, databases, and reference works, then compile and compare findings in group discussions. The workshop culminates in a reflective synthesis of how medical knowledge evolves and how evidence must be critically assessed across time, including contemporary parallels (e.g., social media health claims).

3.3.2 Pedagogical anchoring

• IL: Students evaluate the reliability and validity of historical and contemporary sources. This dual-layered analysis situates IL as both historical awareness and practical competence in evidence-seeking and source judgement.

• DL: Students navigate digital platforms, interpret scholarly material, and integrate sources into structured arguments: core DL competencies.

• Education 4.0: The design is learner-centred and competency-driven, emphasising peer discussion, collaborative synthesis, and reflective evaluation through an authentic, inquiry-oriented task.

3.3.3 Anticipated outcomes and evaluation plan (future work)

Although not yet implemented, the workshop is expected to strengthen students' critical thinking, source criticism, and evidence-based reasoning by requiring explicit claim–evidence–source justification across historical and modern materials. Once delivered, it will be evaluated using the same evaluation/iteration approach described in the Methods section (e.g., structured debriefs and student feedback instruments), enabling comparability with the empirically evaluated nursing workshops.

Indicative learning outcomes

• Understand differences between historical and modern sources of medical knowledge.

• Develop critical thinking and evidence-based evaluation skills.

• Strengthen abilities in information retrieval and source criticism.

• Discuss how medical knowledge evolves over time and the factors influencing this development.

4. Discussion

The discussion below draws on empirical findings from the two implemented nursing workshops (VR and escape room); the design exemplar is included to illustrate planned transferability within nursing, not as an additional source of results. Academic libraries are moving from primarily service-oriented roles to active pedagogical partners that co-design learning with faculties. The makerspace approach (MPF + CDP) at the university library exemplifies this shift: constructive alignment links ILOs to maker-based activities so that immersive technologies and critical source work serve clearly defined aims in students' programmes (Biggs, 1996; Biggs & Tang, 2011; World Economic Forum, 2023). In this sense, the library is no longer merely a site for access but a co-educator capable of integrating IL, DL, and Education 4.0 principles across curricula.

A growing body of research argues that Generation Z learners, digitally native, feedback-oriented, and preference-aligned with interactive formats, require non-traditional, active pedagogies, particularly in medical and health-professional education (Priyanshu et al., 2025; Sundareswaran et al., 2024). Studies report that Gen Z responds favourably to gamification, microlearning, and serious games, and they value technology-mediated, experiential tasks over passive exposure (Buzzetto-Hollywood et al., 2024; Savithri et al., 2024; Saxena & Mishra, 2021).

Our own data echo these claims. In the escape-room cohort, Q1 ("I generally enjoy playing games") averaged 3.97/5, indicating a baseline affinity for game-like learning even before the activity's specific affordances are considered. This matters: Q1 is a proxy for receptivity to gamified, collaborative formats: precisely the kinds of designs Gen Z literature recommends (e.g., gamified challenges, short feedback loops, and peer interaction).

Generation Z is used here as a contextual lens from the literature rather than a measured learner characteristic; substantial within-cohort variability should be assumed.

4.1 From framework to practice: operationalising Education 4.0, IL, and DL

Drawing on two empirically evaluated nursing workshops (VR and Escape room) and one planned nursing adaptation presented for illustration (Medical history in practice), the MPF, operationalised via the CDP, translates a theoretical triad into practical designs:

- Escape-room learning operationalises IL and DL under time-bounded collaboration, encouraging evidence-based reasoning, peer explanation, and debriefing: features that Gen Z studies associate with higher engagement and persistence (Chong et al., 2024; Dodoo & Yawson, 2024).

- VR workshop uses embodied simulation and guided facilitation to amplify cognitive presence while keeping teaching presence visible: aligning with calls to modernize health curricula for digitally native cohorts (Kliesener et al., 2024).

- Medical History in Practice (planned; not yet implemented) places critical source evaluation at the centre, asking students to adjudicate historical remedies against contemporary pharmacology and social-media claims; explicitly fusing IL and DL within an Education 4.0 competency frame.

In each case, constructive alignment is the glue: activities are not "tech for tech's sake" but assessment-aligned tasks that foreground critical thinking, collaboration, and transferable digital competencies: the very outcomes Gen Z-focused scholarship urges institutions to cultivate (Caratozzolo et al., 2021; Nayar & Koul, 2020).

4.2 Implications for health professions curricula

Multiple Gen Z–focused sources in professional education argue for reviving and updating pedagogy; moving beyond transmission-heavy lectures to experiential designs that maintain rigor while matching students' media habits (Priyanshu et al., 2025; Savithri et al., 2024). In medicine and allied health, this includes serious games, simulation, and structured collaboration as core modalities rather than peripheral add-ons (Sundareswaran et al., 2024). Our escape-room and VR results are consistent with this direction: engagement and organization were strong, and learners valued exploration and relevance; at the same time, some desired clearer direct instruction and more visible consolidation: a known tension in active learning with novice cohorts.

This tension is not a defect of active learning per se. Meta-analyses on STEM and health education show that active approaches improve performance even when students feel less confident compared to lectures (Freeman et al., 2014). The design task, then, is to scaffold for visibility: embed micro-reflections, role-to-ILO mapping, and brief evidence logs so that progress is both experienced and recognized by learners. Within the makerspace, these scaffolds can be standardized as part of the library–faculty co-design protocol, ensuring that makerspace activities consistently deliver on cognitive and affective dimensions (Biggs, 1996; Biggs & Tang, 2011).

4.3 The library as a co-educator and scale partner

Positioned at the intersection of information practices, pedagogical design, and technology infrastructures, academic libraries are well placed not only to support but also to scale these approaches across courses and cohorts. Importantly, the MPF and CDP did not arise as abstract frameworks detached from practice; rather, they emerged from collaboration with the nursing programme and are now positioned as transferable resources for future makerspace-supported pedagogical partnerships. This study's findings also speak to a broader LIS discussion of academic librarians as teaching partners, instructional designers, and faculty developers rather than solely service providers or occasional guest instructors (ACRL, 2017; Becksford, 2022; Corrall & Jolly, 2019; Fundator et al., 2025). Recent research further underscores the importance of cross-unit collaboration, iterative course design, and faculty development to sustain such pedagogies (Cantoni et al., 2024; Maxwell, 2025). In this context, the makerspace's CDP, paired with reusable session templates and evaluative instruments, offers an operational mechanism for making the library's pedagogical contribution more visible and easier to adapt across settings allowing variations (e.g., VR, escape rooms, and critical source labs) while preserving coherence between learning design, facilitation, and assessment.

The scalability of the MPF and CDP depends less on any single technology than on the availability of repeatable pedagogical structures, shared facilitation practices, and role clarity across collaborating units. In practical terms, implementation requires staffing for co-design and session delivery, pedagogical and technical training for facilitators, and access to equipment or materials appropriate to the chosen format. However, the cases presented here suggest that scalability can be approached modularly: not all interventions require the same level of technological sophistication, and the core pedagogical logic can be preserved across low-, medium-, and higher-resource formats. Standardized templates, reusable evaluation instruments, and iterative refinement through the CDP reduce the cost of redesign over time and make it more feasible to adapt interventions across courses, cohorts, and disciplinary contexts.

4.4 Limitations and next steps

The VR workshop data reported here represent a subset of a larger evaluative effort. While this article synthesises summary results to inform the Makerspace Pedagogical Framework (MPF), detailed quantitative analyses of the VR intervention, including item-level statistics and psychometric properties of the instruments, are reported in a separate publication (Carlsson et al., 2026). The present study therefore prioritises design implications and cross-case patterns over comprehensive statistical modelling.

Two additional practical constraints warrant note. First, although engagement indicators and qualitative reflections are robust, the study would benefit from triangulation with more direct performance and transfer measures in future implementations, such as scenario-based reasoning tasks and short assessed responses in which students justify a claim using evidence and explicit source references. Second, the effectiveness of immersive and gamified designs is closely tied to facilitation quality; targeted faculty development is therefore recommended, reflecting evidence that instructor readiness is pivotal for Gen Z-aligned pedagogical approaches (Kumar & Gorai, 2025; Weerawardane, 2025).

As a design-oriented, single-institution study grounded in iterative practice, findings are analytically rather than statistically generalisable. The MPF and CDP are offered as transferable design resources whose applicability must be locally adapted and empirically tested in other institutional and disciplinary contexts.

5. Conclusions

This paper introduced the MPF as a constructively aligned conceptual lens for integrating Education 4.0, IL, and DL into higher education curricula through experiential learning activities. Drawing on two empirically evaluated nursing workshops (VR simulations and a gamified escape room) and one planned design exemplar (critical source evaluation), the MPF/CDP approach demonstrates how academic libraries can act as co-educators and pedagogical innovators, bridging traditional literacy instruction with technology-enhanced, student-active learning.

First, contemporary learners, commonly described in the literature as Generation Z, are widely understood to benefit from interactive, non-traditional approaches aligned with digital nativity and active engagement. Our findings echo this trend, showing strong receptivity to gamified and immersive formats, consistent with recent research advocating pedagogical renewal in health and medical education. Second, the makerspace approach (MPF + CDP) translates these theoretical principles into scalable practice. Through the CDP's constructive-alignment process and iterative evaluation, makerspace activities remain outcome-driven and competency-focused rather than "tech for tech's sake".

Future work should address scaffolding for cognitive load management, faculty development in immersive pedagogy, and longitudinal measures of learning transfer. By embedding these refinements, academic libraries can continue to lead in shaping adaptive, interdisciplinary learning environments that prepare graduates for technology-rich professional contexts.

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