Educational Confluences in the Gap from BIM to AI

Driving innovation to evolve didactical frameworks beyond computational design

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Acknowledging the gap in literature, education and practice between BIM and AI, this paper explores the evolution of a compulsory CAAD course 'BIM' (5 ECTS) into the elective 'BIM to AI' (3 ECTS). The elective introduces a collaborative learning framework and demonstrates LLM-enabled computational design and image diffusion techniques. Its outcomes are assessed using classification and evaluation parameters, which enable use-cases to be clustered and analysed to find correlations. The students' survey provides secondary data with which to assess the impact of collaborative learning from the perspective of the learning experience. Highlighting outstanding works and lessons learned, findings emphasize the importance of individual engagement, domain selection and complexity management, besides the role of factual and procedural knowledge, for successful, innovative applications of generative AI in the new landscape of education.

Keywords: *Artificial Intelligence*, *BIM*, *Project-based Learning*, *Collaborative Learning*, *Generative Design*, *Information Management*, *Stable Diffusion*

THE GAP FROM BIM TO AI

While both academia and practice seek to integrate Artificial Generative Intelligence (AGI) applications like Generative Pretrained Transformers (GPT), Large Language Models (LLM), and text-to-image synthesizers (e.g. Midjourney, Stable Diffusion), particularly in the concept and ideation of a project (Fahmy et al., 2024), a significant gap persists between Building Information Modeling (BIM) and Artificial Intelligence (AI). Current BIM models lack the standardization needed for effective LLM interaction. The Industry Foundation Classes (IFC) file format, despite being the open-source standard for Information Exchange with the BIM methodology, has not proven robust enough in practice, effectively preventing data compatibility with LLMs: IFC lacks a dedicated structure to handle time-series data and stores geometry information in a non-compatible fashion with the way AI reads the data (Du et al., 2024). To circumvent this limitation, Lian et al. (2024) propose the use of Graph mapping of BIM models to capture spatial features and element relationship. However, neither IFC nor graph mapping are required by the most relevant ISO 19650 introducing Information Management standards.

From literature emerge a scarcity of specific situations in which AI as a product or service could potentially be used in conjunction with BIM, henceforth referred to as "use case". Kahn et al. (2024) highlight 39 challenges that hinder the BIM-AI implementation, while Gado (2024) identifies "Enhanced Quality Control" with image recognition in construction as one of the few already established use-cases in the practice. In the context of BIM education for architecture, two

studies, Dharmatanna and Wijaya (2025) and Özorhon et al. (2025), attempted to create a framework and integrate AI into design studios. Notably, both highlight a common approach: limiting AI use to specific tasks, to avoid a superficial, mechanical and acritical use of this technology which, according to authors, constrains the students´ creativity.

DRIVING INNOVATION INTO BIM EDUCATION

Even before the widespread of AI technology now available, there has been debate among educators and practitioners regarding the pedagogical approaches to BIM education. Besné et al. (2021) acknowledge that efforts are needed to strengthen the link between academic studies and professional practice. Maile et al. (2023) recommend teaching BIM methodology through theory in lectures and software tutorials, centered on 'Big Open BIM' (multidisciplinary, open-source, software agnostic), and underscore the importance of model-centric communication and project-based learning for practical BIM applications. Borkowski (2023) on the other hand criticises the conventional student tendency to encourage the repetition of factual and procedural knowledge, which theory and tutorials magnify. His work argues for a paradigm shift towards experiential learning that promotes higher order thinking by putting students in direct contact with solving authentic problems rather than just gathering, following and repeating instructions. This education landscape originates the compulsory CAAD subject "BIM" (5 ECTS), taught and tutored by the authors in the Dessau International Architecture M.A. program at the Hochschule Anhalt. The course emphasises a 'learning by doing' posture, shifting a theory- and hands-on-based didactical approach into a project-based collaboration (Fig.1).

Students´ feedback, systematically collected over five years thorough surveys, was pivotal to introducing innovation into the BIM course and refining its pedagogy. This explicit feedback mechanism follows an approach typical of product design, applicable to education (Zhu et al. 2023). Leveraging students´ feedback to innovate the pedagogical approach resulted in refining the BIM course and ended up highlighting the gap with AI. Ultimately the project-based approach simulates a BIM Level 2 project environment with federated and coordinated models on a distributed Common Data Environment (CDE) compliant with ISO 19650 standards. The course leverages the concept of "volume" (per PAS 1192-2:2013) to overcome the lack of disciplinary diversity in BIM education, enabling a class of architecture students to function
as a project team collaboratively designing a multi-building masterplan from individual area projects. It also promotes team roles, distinguishing between BIM modelers, coordinators and manager: one or two students take on leadership roles to ensure model and project coordination, while teaching assistants own project standards development and facilitate knowledge transfer. This structure fosters teamwork while maintaining healthy design competition among individual areas.

The principle of "produce data once, reuse it multiple times" translates into establishing and maintaining a collaboration framework made of BIM documents, a model template and a library of standardized objects with shared parameters. The final product is suitable for Virtual Reality (VR) inspection and aligns content-wise to national building permit requirements. Since technology is the ultimate enabler of the BIM methodology, the course relies exclusively on educational licenses and software available for free for the students at the host university, and in accordance with its privacy policy. This approach resulted in a 'Closed BIM' environment built around *Autodesk Revit©,* with the school's *NextCloud©* platform acting as the CDE for sharing information. *Twinmotion©*

replaced *Enscape*© for the VR scope as soon as a price tag appeared on educational licenses.

Figure 1
CAAD compulsory subject "BIM" : results from 4 th edition Winter 2022

Innovation in the BIM scope, software and methodologies characterised each edition (Table 1), with the delivery team acting as early adopters before the launch of a new semester – though not innovations succeeded. Over the years, the feedback to "which innovation to introduce next" has shifted towards the gap from BIM to AI, particularly:

- integrating AI tools tailored for architectural design with the BIM methodology;
- replacing the software UI with natural language and leveraging AI capability and LLMs to inspect BIM models and execute commands on these 3D databases, particularly those related to repetitive tasks and model coordination;
- separating computational design learning from BIM, with the integration of visual scripting with *Dynamo*© and *Rhino.Inside*© flagged due to the course pace and intensity, and execute-only scripts for model coordination, developed by the coordinators, as the only successful use case;

In addition, the standardisation of project data was often cited as a constraint on creativity, particularly for project-specific 3D objects. Students regularly created elements, disregarding modeling guidelines, especially for final submissions. Thus, fragmented coordination models emerged across the nine BIM course editions. Regrettably, this data could not serve as a multi-project pool for LLM without significant cleansing and restructuring.

AT THE CONFLUENCE OF BIM WITH AI

With this feedback and motivations, the authors chose to investigate the gap from BIM to AI within the collaborative learning framework of the elective subject "BIM to AI" (3 ECTS) which expanded the didactical offer of the compulsory CAAD subject "BIM" (5 ECTS) in winter semester 2025. Students could choose to take each course separately or both together, without having to fulfil the dual learning objectives in a single didactic experience.

The elective is centered around the concept of "use case" previously defined. After a research phase, students selected individual topics according to their interests and goals and presented their progress to the group in bi-weekly workshops that intertwined a schedule of *ex-cathedra* tutorial demonstrations. Research and midterm presentations intercalated the schedule at week three and ten respectively, while the final presentations concluded the 15 weeks cycle of the semester. The course evolved on a shared *Miro*© board where students interacted, posted updates, and responded to challenges. While all participants were exposed to each topic, the elective encouraged individual exploration of the most appropriate toolset for a given use case beyond the learning materials provided. The authors deliberately experimented with a collaborative learning format to democratize access to AI technology by fostering a research environment for students to find and develop additional use cases, identifying resources, and sharing knowledge. Informed consent to the research method and purpose, and respect for the

Edition*	Participants	Didactical framework	Innovation
1st Wi20	39 students	theory + tutorials	course setup, theories & hands-on
2nd Su20	16	theory + tutorials	design exercise & CDE
3rd Wi21	30 +1coordinator (c.)	project-based + theory	project-based team approach & VR
4th Wi22	40 + 2c. +1tutor (t.)	project-based + theory	registers & modeling guidelines
5 th Su22	14 + 1c. +1t.	project-based + theory	(fail) topic: 3d printed concrete
6 th Wi23	27 + 1c. +1t.	project-based + theory	time- aware & (fail) cost-aware modeling
7 th Wi24	26 + 2c. +1t.	project-based + theory	change VR tool to *Twinmotion©*
8 th Su24	13 + 2c. +1t.	project-based + theory	collaborative masterplan *Forma©*
9 th Wi25	23 + 2c. +1t.	project-based + theory	computational design for model check
1 st Wi25	20 participants	collaborative learnin	BIM to AI : AGI use-cases

Table 1
Didactic framework comparing editions of compulsory CAAD subject "BIM" (5 ECTS) & "BIM to AI" elective (3 ECTS)

(*)
Wi : Winter
Su : Summer semester

autonomy of participants in the selection and development of the use case, addressed the ethical concerns of research involving human subjects.

Specifically, the tutorials demonstrated two workstreams of AI tools and techniques designed for concurrent, sequential and iterative usage, with the endpoint of one process informing the other:

1. **LLM-enabled computational design** using free online GPTs with web search capabilities such as *DeepSeek©* and *Copilot©*. Natural language input streamline and enhance the process of coding by interpreting and executing instructions. Both visual scripting and line-coding in Python have been covered, with a focus on APIs integration with prompts that forced the LLM to go through the available documentation first. Applications allow to (a) manipulate geometry, either from scratch (e.g. masses) or using advanced objects with reference geometries (e.g., curtain panels, adaptive components), (b) interact with object parameters for data mapping, and (c) extract and transform data from a coordination model.
2. **Image diffusion** combining natural language with the 3D geometric information of BIM using *Stable Diffusion©* and *ComfyUI©*. This technique enhances design iterations by incorporating AGI's unconscious contributions before detailed 3D modeling begins, as the authors advocates in a previous work (Mondello et al., 2024).

In the wake of an approach well-established in literature (Akbar et al., 2023), the authors developed an evaluation framework to assess the 17 works submitted by 20 students (85% completion rate). Parameters help to neutrally classify student works:

- INPUT : informs the initial data type : Text [*iT*], Geometry [*iG*] and/or Dataset [*iD*]
- OUTPUT : describes the final product to be : Image [*oI*], Code/Script [*oC*], Geometry only [*oG*], BIM Model [*oB*], Application / Notebook [*oA*]
- REUSABILITY : output works for more projects : Yes [*rY*], No, work is one-off project [*rN*]

Use-Case Clusters. The classification parameters group proposals, effectively organizing student´s inspirations and aspirations, as shown in Table 2:

1	2	3	4	5	
X	**X**	**X**	**X**	**X**	*iT*
	X	**O**	**X**	**O**	*iG*
			X	**X**	*iD*
X	**X**				*oI*
	X	**X**	**X**	**X**	*oC*
		X	**X**	**O**	*oG*
			O	**O**	*oB*
			O	**X**	*oA*
	O	**X**	**X**	**X**	*rY*
X	**X**	**O**	**O**		*rN*

Table 2
Use-Case Cluster definition by classification parameters

Legend:
X = applicable
O = optional

Figure 2.
Result Analysis of 17 works categorized in use-case clusters
(1) Text-To-Image
(2) Text + 3d-To-Image
(3) LLM x Computational Design Morphology
(4) LLM x Design Performance Optimization
(5) Generative Design
(33 use cases total)

Complexity
cS : single use case
cD : double
cM : multiple

Performance
pF : Fail
pS : Success
pO : Stand out

Duality with compulsory CAAD:
dN : no duality
dA : single area
dC : coord. model

1. Text-To-Image
2. Text + 3d-To-Image
3. LLM x Computational Design Morphology
4. LLM x Design Performance Optimization
5. Generative Design

Each submitted work elaborates one or more of the use-case clusters, as the iteration of demonstrated and non-demonstrated AI tools & techniques is a foundational value that this methodology pursues.

Therefore, a second group of parameters, specific to the context of this paper, was additionally introduced to evaluate each work submitted:

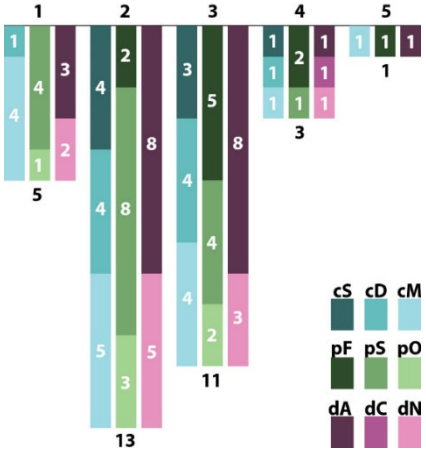
- COMPLEXITY : address the use-cases count : Single [*cS*], Double [*cD*], Multiple [cM]
- PERFORMANCE : evaluate the result of each use-case, whether the work achieves its original ambition: Fail [*pF*], Succeed [*pS*], Stand out [*pO*]. Communicational aspects are not included – lessons-learned out of negative results are the essence of collaborative learning.
- DUALITY : serve both the elective and the CAAD compulsory : Yes, one area only [*dA*], Yes, for the coordination model [*dC*], Not for CAAD [*dN*]

Results

Analysis of the 33 use-cases presented by 17 works reveals distinct trends in the evaluation parameters.

Domain selection and complexity management play a key role in performance.
Text-to-image use-case always succeeds (0% pF) despite the complexity, reflecting a robust domain with established practices. Use-cases involving LLMs, both computational design and optimization, show higher failure rates instead (56% pF, weighted average), highlighting technical challenges.

The text+3D-to-image cluster achieves balanced results, with moderate successes (61%



pS) and some stand outs (23% pO). Across all works, the point-biserial correlation between existing duality (dA + dC) and positive performance (pS + pO) indicates no strong relationship (-0.05), while complexity (cD + cM) correlates negatively (-0.28) with standout results (pO), suggesting lower complexity modestly enhances outcomes. Use-cases with most work and highest success rates are those closest to the techniques demonstrated. These results, corroborated by the secondary data collected by 14 feedback surveys presented in Table 3 underscore the importance of factual and procedural knowledge, suggesting that Borkowski's (2023) is not yet applicable to AI, at least in the restricted space of an elective course. Future studies should further refine these findings

[14] %	Area : SubTopic	Representative comments
5 *36%*	(A) Encouragement of Creative Freedom	"Freedom of having different kind of idea"; "Encouraged to have fun"; "Freedom to expand on each use case"
4 *29%*	(A) Appreciation of Collaborative Learning Framework	"Friendly, interactive, and engaging teaching"; "Never boring"; "Class easy to follow and engaging."
2 *14%*	(A) Responsiveness and Support	"Got help whenever I asked for it"
4 *29%*	(B) Difficulty with Advanced Tools	"As a beginner… it got harder for me to keep up"; "Complexity of each tool was challenging"
3 *21%*	(B) Request for More Tutorials	"More tutorials… will be helpful"; "I would have liked more detailed software explanations"
2 *14%*	(B) Overload from Tool Diversity	"Got confused about which one I should focus on"
2 *14%*	(C) Duality with compulsory CAAD	"If I knew it was so in-depth… I would've thought more before taking it"; "Course description does not fit both"
2 *14%*	(C) Suggesting Different Didactical Framework	"Try using the same base model and improving outputs"; "Be more directive and restrictive to guide projects"
3 *21%*	(C) Ambiguity of Use-Case based approach	"Didn't understand requirements at the beginning"; "Our task was confusing at the start"

Table 3. Course Survey Analysis (frequency over 14 responses) & Feedback Areas: (A) Collaborative Learning (B)Technical infrastructure (C) Learning Experience

Lessons (collaboratively) learned

Figure 3 presents a sample of student-generated use cases, showcasing outstanding performance and significant lessons learned.

Image diffusion explorations yielded remarkable results when AGI produced unexpected outcomes. In Use-Case A [*cS_pO_dA*], the student derived a segmentation map by classifying the BIM model into objects and categories, rather than mapping its materials. This unorthodox approach generated "Escherian" images with distorted perspective and intricate vegetation climbing facades and roofs. As a result, the BIM project focus shifted to greenery.

Disciplined, reflective engagement with AI correlated directly with stand-out performance. For example, while Low-Rank Adaptation (LoRA) for fine-tuning image atmosphere was discussed but not demonstrated, Use-Case B [*cS_pO_dN*] integrated it into an original *ComfyUI*© workflow. The LLM-enabled computational design experiments also stood out due to their engagement. Use-Case C [*cS_pO_dN*] used LLM to conceptualise and execute a volume voxelation. Notably, the LLM promoted to develop the code on a sphere before importing facade geometry using *Rhino.Inside*©. Also Use-Case D [*cS_pO_dN*] scripted a fully parameterised design and exported the geometry via *Rhino.Inside*©. Both students had no previous programming experience with coding, yet they stand out in orchestrating the creation of complex Python scripts from scratch for the single use case "LLM x Computational Design Morphology". These works more than others demonstrate how LLM interaction can support better line coding than visual scripting. Students had a more meaningful and active interaction, also in absence of previous knowledge, when the AGI generates code directly, instead of returning instruction on what nodes to use and how to wire them. This dynamic pushed many students out of their comfort zone, often constrained within visual scripting. These outstanding works were achieved with one use-case and no duality, except use-case A dual application to its own BIM project area.

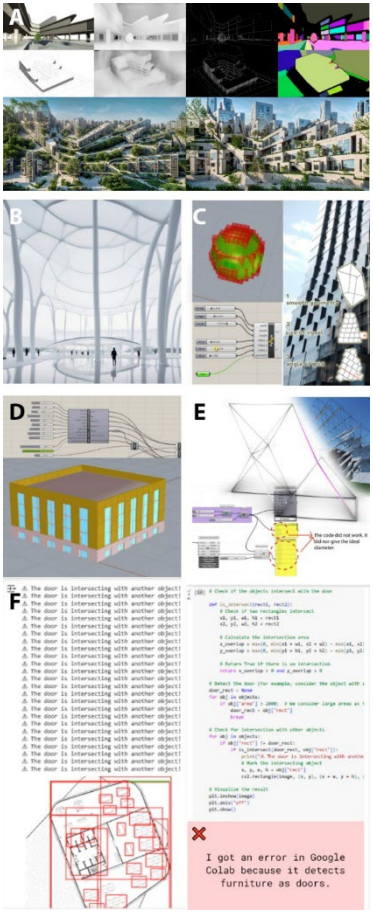


Figure 3
"BIM to AI" elective results - 1st edition Winter 2025

A : segmentation x BIM classification
[cS_pS_dA]
Text + 3D-to-image
[iT_iG_oI_oC_rY]

B : LoRA usage
[cS_pO_dN]
Text + 3D-to-image
[iT_iG_oI_oC_rY]

C : Voxelation of imported geometry
[cS_pO_dN]
LLM x Comp. Design Morphology
[iT_iG_oC_oG_rY]

D : LLM-assisted parametric design
[cS_pO_dN]
LLM x Comp. Design Morphology
[iT_oC_oG_rY]

E : LLM-assisted structural design
[cM_sF_dN]
LLM x Design Performance Opt.
[iT_iG_iD_oI_ oC_oG_oB_rN]

F : clash detection x image recognition
[cM_sF_dA]
Generative Design [iT_iG_iD_oI_oC_ oA_rY]

The only Use-Case with a dual application to the compulsory CAAD subject´s coordination model [cS_pS_dC], centralising the data collection and model clean-up from linked files, was created by the BIM coordinator of the CAAD course. The rest of the elective students showed no willingness to experiment with complex 3D databases, favoring applications functional to their own projects. Despite this one success, merging computational design with BIM-driven information management proved again irksome, confirming surveys´ feedback.

Collaborative learning yielded benefits from bold failures. Use Case E [cM_pF_dN] sought to optimise the structural design of a space frame, having successfully delivered both text-to-image [pS] and text+3D-to-image [pS] without duality. The student, who lacked subject matter expertise, identified inconsistencies in the Python script generated by LLM that returned absurd results.

This underlines the need for human technical feedback in AI-driven design, reinforcing with additional arguments the posture of Dharmatanna and Wijaya (2025) and Özorhon et al. (2025). Use Case F [cM_pF_dN], focused on generative design, successfully delivered both Text + 3D-to-Image [pS] and LLM x Computational Design Morphology [pS], without duality, but failed to implement generative floor plan desgin. Despite the LLM suggesting an original approach with clash detection metrics in a *Jupyter Notebook*©, inconsistencies in the input dataset (rotated floor plans and unhighlighted furniture) caused the image recognition to fail most of the times, with time-constrains due to the low time allocated to the elective being its root cause.

CONCLUSIONS

The collaborative learning framework has shown great promise in fostering individual engagement with AI and providing a platform for exposure to use-cases, lessons learned and knowledge sharing. This approach needs validation by other academic contexts, particularly educational formats other than a 3 ECTS elective. A studio format incorporating multidisciplinary subjects (e.g. structural or environmental design) seems particularly promising.

Bridging the gap between BIM and AI in the new educational landscape requires tackling crucial issues. Firstly, domain selection and complexity management. Most students benefit from guided, first-time applications of new technologies. Outstanding works from the

collaborative learning format were rooted in demonstrated tutorials, emphasising the importance of factual and procedural knowledge for exploring new domains. In addition, the balance between technology application and pure design remains a crucial aspect. Design often adds complexity that makes it difficult to focus on technology applications like the one AI requires – especially in short format, other than a studio or laboratory. Engaging with subject matter experts and replicating successful use-cases is therefore essential to begin navigating the steep learning curve of this technology. Finally, the most critical aspect of enabling AI-driven information management in BIM lies in the quality and quantity of structured data available for experimentation, beginning with limitations of the IFC format (Du et al., 2024). Future efforts should aim at creating and experimenting with a BIM data lake, which would significantly enhance future studies like this one.

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