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Autodesk Forma Site Design como Herramienta Pedagógica para el Análisis Bioclimático: Un Fraccionamiento Residencial como Caso de Estudio

Autodesk Forma Site Design as a Pedagogical Tool for Bioclimatic Analysis: A Residential Subdivision Case Study

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Resumen: Las plataformas BIM nativas en la nube ofrecen capacidades integradas de análisis ambiental que siguen estando poco exploradas en la educación arquitectónica. Este estudio de caso exploratorio documenta el uso de Autodesk Forma Site Design como herramienta pedagógica para el análisis bioclimático en etapas tempranas de diseño. Diecinueve estudiantes de pregrado en arquitectura del Tecnológico de Monterrey, Campus Monterrey, analizaron un fraccionamiento residencial real proporcionado por un socio de la industria durante dos sesiones presenciales de cinco horas cada una. Cuatro equipos poblaron simultáneamente un modelo compartido en la nube mediante importaciones de masas de Revit y herramientas nativas de Forma, para después realizar análisis de horas de sol, viento, potencial de deslumbramiento y sombras en sus zonas asignadas. Cada equipo desarrolló una matriz o síntesis comparativa de prototipos y justificó la selección de un prototipo habitacional recomendado con base en criterios ambientales derivados de sus análisis. Además, las reflexiones individuales fueron codificadas cualitativamente para identificar evidencias de aprendizaje percibido, razonamiento ambiental basado en datos, síntesis multicriterio y colaboración. Los resultados sugieren que los estudiantes pudieron traducir simulaciones ambientales en argumentos bioclimáticos multicriterio, a pesar de su limitada exposición previa a la plataforma. Las reflexiones indicaron cambios conceptuales percibidos sobre orientación, diseño pasivo y uso de datos ambientales en la toma de decisiones de diseño. Autodesk Forma Site Design se perfila como una herramienta pedagógica viable para el análisis ambiental colaborativo en la educación arquitectónica de pregrado, aunque los hallazgos deben interpretarse dentro de los límites de un estudio de caso exploratorio con muestra reducida.

Abstract: Cloud-native BIM platforms offer embedded environmental analysis capabilities that remain underexplored in architectural education. This exploratory case study documents the use of Autodesk Forma Site Design as a pedagogical tool for early-stage bioclimatic analysis. Nineteen undergraduate architecture students at Tecnológico de Monterrey, Monterrey Campus, analyzed a real residential subdivision provided by an industry partner during two five-hour in-person sessions. Four teams simultaneously populated a shared cloud model using Revit mass imports and native Forma tools, and then performed solar-hours, wind, glare-potential, and shadow analyses in their assigned zones. Each team developed a comparative prototype matrix or synthesis and justified the selection of a recommended housing prototype based on environmental criteria derived from its analyses. Individual reflections were also qualitatively coded to identify evidence of perceived learning, data-grounded environmental reasoning, multi-criteria synthesis, and collaboration. The results suggest that students were able to translate environmental simulations into multi-criteria bioclimatic arguments despite limited prior exposure to the platform. The reflections indicated perceived conceptual shifts regarding orientation, passive design, and the use of environmental data in design decision-making. Autodesk Forma Site Design appears to be a viable pedagogical tool for collaborative environmental analysis in undergraduate architectural education, although the findings should be interpreted within the limits of an exploratory case study with a small sample size.

1. Introduction

Building Information Modeling (BIM) has become an increasingly important component of architectural education, not only as a platform for documentation and coordination, but also as a medium for integrating environmental performance, sustainability criteria, and design decision-making. Previous studies have shown that BIM-based pedagogical strategies can support project-based learning, energy simulation, and the evaluation of sustainable design alternatives by allowing students to connect design variables with measurable performance outcomes (Shen, Jensen, Wentz, & Fischer, 2012; Shen, Jensen, Fischer, & Wentz, 2012; Shahverdi, Mostafavi, Roodkoly, Zomorodian, & Homayouni, 2024; Nguyen & Adhikari, 2025). In this context, BIM can help bridge the persistent gap between conceptual discussions of sustainability and the operational tools used in professional architectural practice.

This shift is particularly relevant for early-stage design education. Decisions related to orientation, massing, facade exposure, shading, daylight availability, and natural ventilation are often established before detailed technical development begins. Environmental simulation at this stage can therefore provide students with evidence for evaluating design alternatives before they become fixed formal or constructive decisions (Li & Hong, 2020; Bernett, Kral, & Dogan, 2021; Rizaoglu & Voss, 2020). Passive design strategies, including solar control, daylight management, shading, and wind-driven ventilation, require students to understand climate not as background information, but as an active design parameter (Altan, Hajibandeh, Tabet Aoul, & Deep, 2016; Cillari, Fantozzi, & Franco, 2021; Mashruwala & Jadav, 2023). However, in many architectural curricula, environmental analysis is still taught through fragmented workflows, standalone software, or simplified exercises that are not fully connected to real design problems.

Another challenge concerns the relationship between simulation output and design reasoning. Students may be able to generate environmental visualizations, but they do not always know how to interpret them, compare alternatives, or translate them into defensible design arguments. This is especially important in bioclimatic design education, where no single variable is sufficient to determine design quality. Solar exposure, wind access, glare potential, and shadow behavior often produce competing implications that require synthesis rather than isolated interpretation. For this reason, pedagogical exercises that combine environmental simulation with comparative matrices, reflective assessment, and design justification can help students move from visual analysis toward evidence-based decision-making.

At the same time, BIM education is increasingly shaped by collaborative and cloud-based workflows. Cloud-based BIM platforms and common data environments support shared models, real-time coordination, team-based learning, and professional communication practices that resemble contemporary AEC workflows (Basson & Smallwood, 2026; Hemmerling & Maris, 2020; Chenah & Boton, 2026; Herrera, Vielma, & Mu noz, 2018). These platforms create opportunities for students to work simultaneously within a common model, observe the consequences of design decisions across larger systems, and coordinate individual contributions within collective design tasks. Yet the pedagogical implications of cloud-native collaboration for environmental analysis remain less developed than its applications in model coordination, clash detection, or construction management.

Autodesk Forma Site Design occupies a relevant position within this emerging context because it combines early-stage site modeling, cloud-based collaboration, and embedded environmental analysis in a single platform. Its tools allow users to evaluate solar hours, wind behavior, daylight or glare potential, shadows, and other site-related conditions during the conceptual design phase. Recent studies have begun to examine Autodesk Forma Site Design and related cloud-based BIM tools for climate-responsive design and environmental performance assessment (Daniel & Sood, 2025; Chelaru, Onuţu, Ungureanu, Volf, & Şerbănoiu, 2025; Quedas Campoy, Maria Rabelo Souza, Izidoro, & Emanuel Scanavino, 2025). Nevertheless, evidence on its pedagogical use in undergraduate architectural education remains limited, particularly in exercises where students must collaboratively build a shared model, analyze a real development site, compare multiple housing prototypes, and justify bioclimatic recommendations.

This paper addresses that gap through an exploratory case study conducted in February 2026 in an undergraduate BIM course at Tecnologico de Monterrey. Nineteen architecture students used Autodesk Forma Site Design to analyze a real residential subdivision provided by an industry partner. Working in four teams, students populated a shared cloud model using both Revit mass imports and native Forma tools, conducted solar-hours, wind, glare-potential, and shadow analyses, and developed comparative prototype matrices to support their final recommendations. The study documents how students used Forma Site Design to produce multi-criteria bioclimatic arguments, how the shared cloud model shaped collaborative work, and how individual reflections revealed perceived learning related to orientation, passive design, and environmental data interpretation.

1.1 Objective

The objective of this exploratory case study is to document the pedagogical potential of Autodesk Forma Site Design as a collaborative platform for early-stage bioclimatic site analysis in undergraduate architectural education. Rather than measuring learning gains through a controlled experimental design, the study examines the analytical outputs, student-generated comparative scoring, and reflective evidence produced during a short, practice-based instructional intervention. Specifically, the study examines:

- Whether students with limited prior exposure to Autodesk Forma Site Design can produce multi-criteria environmental analyses within a constrained time frame of ten contact hours

- How a collaborative real-time modeling workflow, in which students simultaneously populate a shared cloud model, supports spatial awareness and team-based environmental analysis.
- How students translate solar–hours, wind, glare–potential, and shadow analyses into comparative prototype matrices and bioclimatic design recommendations.
- What perceived conceptual shifts are evidenced in students' reflections regarding orientation, passive design, and the use of environmental data in early-stage design decision-making.
- What advantages and limitations emerge when students model housing prototypes through Revit mass imports versus native Forma geometry tools.

2. Methods

2.1 Research Design

This study followed an exploratory single-case study design focused on the pedagogical implementation of Autodesk Forma Site Design in an undergraduate architecture course. The study did not aim to measure learning gains through a controlled experimental design. Instead, it documented the analytical outputs, student-derived comparative scoring, and reflective evidence produced during a short, practice-based instructional intervention. The unit of analysis was the use of a cloud-native BIM workflow to support collaborative bioclimatic site analysis and prototype evaluation in a real residential development.

The empirical corpus included four team-based Forma Boards, four comparative prototype matrices or narrative syntheses, four final prototype recommendations, 19 individual written reflections, and instructor observations during the two in-person sessions. These sources were analyzed to examine how students generated environmental simulations, interpreted multi-criteria results, justified prototype selection, and reflected on the relationship between environmental data and early-stage design decisions.

2.2 Instructional Context

The exercise was embedded in AR3002C (BIM Design and Management), a BIM concentration elective at Tecnologico de Monterrey's School of Architecture, Art and Design (Tecnológico de Monterrey, 2022). Nineteen undergraduate architecture students participated in two 5-hour in-person sessions in February 2026.

The selected site was a real residential development located in Apodaca, Nuevo Leon, Mexico. The project was provided by an industry partner affiliated with a Tecnologico de Monterrey initiative that connects students with real clients and live projects, offering professional exposure within the academic curriculum. In accordance with client confidentiality agreements, site-specific imagery, cadastral details, and the developer's identity are not disclosed in this publication. Spatial analysis and methodological findings are therefore reported at the level of urban morphology, prototype performance, and environmental design reasoning. The climate of Apodaca is hot semi-arid (BWh), with high summer temperatures and mild winter conditions, making solar exposure, shading, glare control, and wind access relevant design variables for bioclimatic analysis.

2.3 Activity Brief and Required Deliverables

To ensure consistency across teams, students received a structured activity brief specifying the objectives, required analyses, Forma Board organization, and reflection prompts. The brief stated that the objective was not only to generate environmental visualizations, but to construct a technical argument about which housing prototype or prototypes performed better in terms of comfort, energy efficiency, and relationship with the surrounding context.

Each team was required to submit a nine-panel Forma Board organized as a sequential narrative from site context to design recommendation. The required panels were: (1) team cover, (2) climatic context and critical days, (3) solar-hours analysis, (4) wind analysis, (5) glare-potential analysis, (6) shadow study, (7) comparative prototype synthesis, (8) recommended prototype with technical justification, and (9) individual reflections. The brief emphasized that the comparative synthesis matrix was the core of the argument, because the final recommendation had to be coherent with the environmental evidence presented in the previous panels.

For replicability, Table 1 summarizes the required analytical components of the activity.

2.4 Methodology Overview

Figure 1 illustrates the complete workflow from project inputs to final deliverable, organized across the two sessions. The methodology comprised five sequential phases: site preparation, prototype modeling through a dual workflow, collaborative real-time model assembly, environmental analysis, and Forma Board production.

2.5 Team Structure and Zone Assignment

Students were organized into four teams, each assigned to a distinct zone of the development: northeast, northwest, southeast, or southwest. This structure ensured that the teams collectively reconstructed the full residential development as a single shared Forma project. Before the analysis sessions, one student cleaned the original AutoCAD DWG master plan, retaining only the road network and lot boundaries to serve as the shared base layer.

Within each team, responsibilities were further subdivided. Each student was assigned one of the housing typologies present in the corresponding zone. Each typology included four facade variants, and students were required to place the correct facade orientation according to the actual lot layout. Students could model their assigned typology either as a Revit mass imported into Forma or directly

Table 1 Required Forma Board structure and analytical purpose.

Panel	Required component	Required content	Analytical purpose
1	Team cover	Team members, project name, date, and general site image	Identify the team and project context
2	Climatic context and critical days	Temperature, wind speed, radiation, relative humidity, cloud cover, and selected critical days	Establish the climatic basis for the analyses
3	Solar-hours analysis	Solar exposure heat maps for critical days and comparison of more and less exposed prototypes	Evaluate solar exposure by orientation, facade, and lot position
4	Wind analysis	Dominant wind simulation, airflow behavior, and identification of units with greater or lower ventilation access	Relate wind behavior to orientation, lot position, and natural ventilation potential
5	Glare-potential analysis	Facade-based analysis of glare-potential conditions and critical orientations	Identify visual comfort risks and compare facade exposure
6	Shadow study	Shadow behavior during critical seasonal conditions	Understand how adjacent volumes affect solar access and outdoor conditions
7	Comparative prototype synthesis	Matrix or synthesis comparing all prototypes according to the main environmental analyses	Integrate multiple variables and support the final selection
8	Recommended prototype	Selection of the best-performing prototype with technical justification and possible design strategies	Translate simulation evidence into a bioclimatic design recommendation
9	Individual reflections	Individual responses to conceptual, metacognitive, and collaborative prompts	Document perceived learning and interpretation difficulties

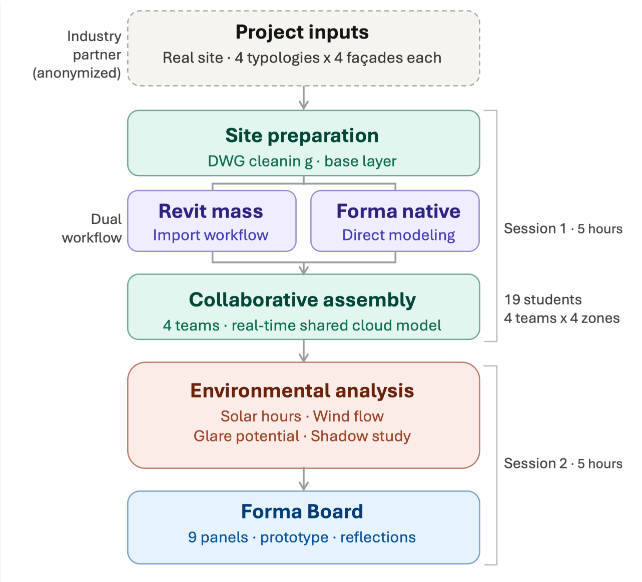

Figure 1 Methodology workflow diagram.

in Forma using its native geometry tools. This dual-track approach was intentional: it exposed students to two early-stage modeling workflows and allowed them to compare modeling precision, ease of use, and simulation readiness across input types. One additional team member was responsible for adding road geometry and vegetation to the shared Forma model.

2.6 Collaborative Real-Time Model Assembly

The most technically demanding phase of the exercise was the assembly of the complete site model. All students worked simultaneously within the same shared Autodesk Forma Site Design project. Each student modeled assigned housing prototypes at the massing level, including sufficient volumetric definition to cast shadows and affect wind flow, and then populated the corresponding lots in the shared cloud model.

This real-time collaborative workflow allowed students to observe the site model as it was being collectively built. As one student placed units in one sector, other students could see the development grow in adjacent sectors, enabling spatial awareness, informal peer checking, and coordination across team boundaries. The assembly phase required approximately three to four hours of the first session, reflecting both the complexity of the task and its centrality to the learning experience.

2.7 Environmental Analysis Protocol

Once the full model was assembled, each team conducted four environmental analyses using Forma's built-in tools within its assigned zone:

- **Solar-hours analysis:** Students generated sun-exposure heat maps on the ground plane, roofs, and facades for critical days identified through climatic review.

- **Wind analysis:** Students analyzed dominant wind behavior, identifying airflow patterns, zones of higher and lower exposure, and the potential for natural ventilation across housing units.

- **Glare-potential analysis:** Students used facade-based exposure outputs to identify orientations and areas with higher potential for visual discomfort.

- **Shadow study:** Students examined shadow projections during critical seasonal conditions and selected time steps, with attention to how shadows affected adjacent units, open spaces, and facade exposure.

Results were documented in a structured nine-panel Forma Board following a prescribed narrative sequence: cover, climatic context, solar-hours analysis, wind analysis, glare-potential analysis, shadow study, comparative prototype synthesis, recommended prototype with justification, and individual reflections. This structure was intended to guide students from environmental data collection toward comparative interpretation and evidence-based design argumentation.

2.8 Student-Derived Prototype Scoring

Each team produced a comparative prototype synthesis matrix or narrative comparative assessment as part of the required Forma Board. The synthesis compared the housing prototypes and facade variants assigned to the team according to the four main environmental analyses: solar hours, wind performance, glare potential, and shadow performance. The purpose of this synthesis was to support each team's selection of the most appropriate prototype within its assigned zone.

The score reported in Table 2 is a student-derived comparative performance score, not an instructor grade. For each recommended prototype, the reported value corresponds to the average score assigned by the team across the environmental criteria included in its comparative synthesis.

The student-derived comparative performance score was calculated using Equation 1.

$$Score_{avg/5} = \frac{S_{solar} + S_{wind} + S_{glare} + S_{shadow}}{4} \quad (1)$$

where (S_{solar}) represents the team's evaluation of solar-hours performance, (S_{wind}) represents wind and natural ventilation performance, (S_{glare}) represents glare-potential performance, and (S_{shadow}) represents shadow-study performance. When teams used categorical labels, rankings, or partial numerical scales, these values were interpreted and normalized to a 1-5 scale for reporting consistency. The resulting score should be read as evidence of each team's comparative design reasoning within its assigned zone, rather than as a standardized environmental performance metric or a direct cross-team ranking.

For Team 3, the students submitted a narrative comparative assessment rather than a complete numerical matrix. Its normalized score was derived from the evidence explicitly stated in the synthesis: balanced solar exposure, favorable natural ventilation, partial solar-control advantages, and limited direct evidence regarding glare potential. The corresponding normalized values were ($S_{solar} = 4$), ($S_{wind} = 4$), ($S_{glare} = 3$), and ($S_{shadow} = 4$), resulting in an average score of 3.75, rounded to 3.8.

2.9 Reflective Assessment and Qualitative Coding

Individual written reflections were structured around four dimensions established in the activity brief: conceptual and technical learning, metacognitive learning, collaborative process, and collaborative reflection. The prompts asked students to compare their initial assumptions with the simulation results, identify the most revelatory environmental variable, describe moments of data comprehension, discuss interpretive difficulties, explain team decision-making, and reflect on the experience of building a shared visual narrative. A minimum of 150 words per student was required.

The reflections were analyzed through a directed qualitative coding process. Each individual reflection was treated as one unit of analysis (n = 19). Coding was based on the presence or absence of recurring themes within each reflection. The initial coding categories were informed by the four reflection dimensions established in the activity brief, while additional subthemes were identified during review of the responses. The final coding categories included data-grounded environmental reasoning, multi-criteria synthesis or trade-off reasoning, interpretation difficulty, collaborative interpretation and team consensus, visual communication through Forma Board, and workflow comparison with Revit or previous tools.

Because the coding was conducted by the author as instructor-researcher and did not include inter-rater validation, the findings are interpreted as descriptive and exploratory evidence of self-reported learning rather than independently validated qualitative measurement.

3. Results

3.1 Technical Outputs and Prototype Recommendations

All four teams completed the required analytical sequence within the allocated time. The submitted Forma Boards included climatic context, solar-hours analysis, wind analysis, glare-potential analysis, shadow study, a comparative prototype synthesis matrix or narrative synthesis, a justified prototype recommendation, and individual reflections. These deliverables were consistent with the activity brief, which asked students not only to generate environmental visualizations, but also to construct a technical argument about the best-performing housing prototype or prototypes in terms of comfort, energy efficiency, and relationship with the surrounding context.

The submitted boards showed that teams used the environmental analyses to compare prototype performance and justify a final recommendation. The comparative syntheses included solar hours, wind performance, glare po-

Table 2 Summary of recommended prototypes and justification criteria per team.

Team	Zone	Recommended Prototype	Primary Criterion	Key Trade-off	Team-derived Score (avg/5)
1	SW	Model 231, Facade 2	Wind + solar balance	Moderate W-facade glare	4.1
2	NE	Model 220, Facade 2	Solar + shadow	Lowest glare potential	3.5
3	NW	Model 186, Facade 4	Solar + ventilation	Limited glare evidence	3.8
4	SE	Model 186, Facade 1	Wind + passive design	W-facade critical at 6 pm	4.75

Note. The team-derived score reports the average environmental performance score assigned by each team to its recommended prototype in the comparative synthesis matrix. When teams submitted narrative or categorical comparisons rather than complete numerical matrices, scores were normalized from the explicit evidence provided in the synthesis. Scores summarize student evaluations of solar hours, wind performance, glare potential, and shadow performance. They are used to document comparative reasoning within each assigned zone and should not be interpreted as standardized environmental performance metrics or direct cross-team rankings.

tential, and shadow behavior as decision criteria. In several cases, students explicitly recognized that the selected prototype was not necessarily the best in every isolated analysis, but rather the most balanced option across the criteria evaluated.

For example, Team 1 compared prototypes 186, 220, and 231 according to solar hours, wind, glare potential, and shadow behavior, identifying Model 231, Facade 2, as the most favorable overall option. Team 2 evaluated facade alternatives for Model 220 and selected Facade 2 based on the highest average score across solar hours, wind, glare potential, and shadow performance. Team 3 selected Model 186, Facade 4, based on its balanced solar exposure, natural ventilation potential, proximity to the park, and distance from the development boundaries where higher noise levels could occur. Because Team 3 submitted a narrative comparative assessment rather than a complete numerical matrix, its score was normalized from the evidence explicitly stated in the synthesis. Team 4 identified Model 186, Facade 1, as the best-performing option in its zone, reporting a score of 4.75 based on climatic performance, wind, shadow behavior, and urban implantation.

Across the submitted boards, prototype recommendations were therefore based on multi-criteria comparison rather than on a single environmental variable. Table 2 summarizes each team's recommended prototype, main decision criterion, key trade-off, and student-derived average performance score.

The synthesis matrices and final recommendations also showed that students interpreted environmental performance as a contextual condition. Prototype performance was linked not only to facade orientation, but also to lot position, adjacency to other units, surrounding open areas, street configuration, and the relationship between neighboring volumes. This was visible in recommendations that described central positions, corner lots, adjacency to parks, exposure to development boundaries, and relationships between houses as factors affecting solar exposure, wind access, shadow behavior, and comfort.

3.2 Modeling Workflow and Platform Use

The activity also generated evidence regarding how students perceived Autodesk Forma Site Design as a modeling and analysis platform. Several reflections described Forma as a visual, fast, and integrated tool for understanding environmental conditions during early design. Students emphasized that the platform helped them visualize solar exposure, shadows, wind behavior, and daylight-related outputs in a clearer way than fragmented workflows.

A smaller group of reflections explicitly compared Forma with previous tools or workflows. Some students noted that Forma allowed several environmental analyses to be conducted in one place, whereas previous courses required separate platforms, manual interpretation, or sequential workflows. One student specifically stated that Revit offered greater precision and comfort for mass modeling, while Forma was more useful for solar analysis and preliminary studies. These comments suggest that students perceived a trade-off between modeling precision and analytical immediacy.

Because only a subset of reflections explicitly addressed workflow comparison, these findings should be interpreted as exploratory. They suggest that Forma was valued primarily for visual feedback, integrated analysis, and rapid interpretation, while Revit or previous tools were associated with modeling precision, familiarity, or more fragmented analytical processes.

3.3 Qualitative Coding of Individual Reflections

Directed qualitative coding of the individual reflections (n = 19) identified six recurring themes related to students' perceived learning, interpretation process, and collaborative experience. Each reflection was treated as one unit of analysis, and coding was based on the presence or absence of each theme. Table 3 summarizes the coding categories, operational definitions, and frequencies observed across the reflections.

The most consistent theme was data-grounded environmental reasoning, which appeared in all 19 reflections. Students repeatedly referred to solar exposure, wind direction, shadow behavior, facade orientation, lot position, climatic conditions, and visual simulation outputs when explaining design implications. This indicates that the activity helped students connect abstract bioclimatic principles with site-specific evidence.

The second most frequent theme was multi-criteria synthesis, identified in 17 of the 19 reflections. Students recognized that comfort and environmental performance

Table 3 Summary of qualitative coding themes from individual reflections.

Coding theme	Operational definition	Frequency
Data-grounded environmental reasoning	The reflection refers to environmental evidence such as solar exposure, facade orientation, wind direction, shadow behavior, lot position, climatic conditions, or visual simulation outputs to explain design decisions.	19/19
Multi-criteria synthesis / trade-off reasoning	The reflection recognizes that design decisions required comparing several environmental variables rather than relying on one isolated analysis.	17/19
Interpretation difficulty / need for clarification	The reflection identifies difficulty, uncertainty, or a need for clarification when interpreting simulation outputs, including shadows, wind, glare or daylight potential, scales, ranges, or relationships among variables.	10/19
Collaborative interpretation and team consensus	The reflection describes team discussion, division of analytical tasks, disagreement, consensus-building, or the value of multiple perspectives in reaching the final recommendation.	12/19
Visual communication through Forma Board	The reflection describes Forma or the Forma Board as useful for visualizing, organizing, synthesizing, or communicating environmental information.	13/19
Workflow comparison with Revit or previous tools	The reflection compares Forma with Revit, previous analysis tools, manual processes, or fragmented workflows in terms of speed, precision, integration, or ease of interpretation.	8/19

could not be evaluated through a single variable. Several reflections described the need to compare solar hours, wind, shadows, glare potential, and urban position before selecting or modifying a prototype. This supports the role of the comparative matrix as a bridge between environmental visualization and design decision-making.

Interpretation difficulty appeared in 10 reflections. However, the difficulty was not limited to glare potential. Students also reported challenges when interpreting shadows, wind behavior, graphic scales, ranges, and the relationship among multiple variables. This finding suggests that environmental simulation outputs require guided interpretation, especially when students must translate visual outputs into design criteria.

Collaborative interpretation and team consensus appeared in 12 reflections. Students described dividing the analysis by variable, discussing different interpretations, comparing results collectively, and reaching decisions based on shared criteria. In several cases, students stated that different perspectives helped them identify aspects they would not have noticed individually. This indicates that collaboration contributed not only to task distribution, but also to the interpretation of environmental evidence.

Visual communication through Forma Board appeared in 13 reflections. Students described Forma and the Forma Board as useful for making environmental data clearer, more visual, and easier to communicate. This was particularly relevant because the final deliverable required students to transform separate analyses into a shared visual narrative.

Workflow comparison with Revit or previous tools appeared in 8 reflections. These comments highlighted Forma's capacity to integrate multiple analyses in a single platform and to make environmental feedback easier to visualize. At the same time, some students identified Revit or previous workflows as more familiar or precise for modeling tasks. This suggests that students perceived Forma Site Design less as a replacement for existing BIM tools and more as an early-stage platform for environmental interpretation and decision support.

Together, the coded reflections suggest that Autodesk Forma Site Design supported three linked learning processes in this exploratory case: environmental visualization, comparative prototype evaluation, and collaborative interpretation. These findings should be interpreted as descriptive and self-reported evidence from a small case study rather than as generalizable proof of learning gains.

4. Discussion

This exploratory case study contributes to the discussion on how cloud-native BIM platforms can support environmental design education at early design stages. The results suggest that Autodesk Forma Site Design allowed students to move from environmental visualization toward comparative bioclimatic reasoning within a short instructional format. This finding aligns with previous studies arguing that BIM-based and simulation-supported pedagogies can help students connect design variables with measurable environmental performance (Shen, Jensen, Wentz, & Fischer, 2012; Shahverdi et al., 2024; Nguyen & Adhikari, 2025). However, the present case adds a more specific contribution: students did not only generate simulations, but used solar-hours, wind, glare-potential, and shadow analyses to compare housing prototypes and justify design recommendations.

The first objective concerned whether students with limited prior exposure to Autodesk Forma Site Design could produce multi-criteria environmental analyses within ten contact hours. The completed Forma Boards indicate that this was possible when the activity was structured through a clear sequence of tasks, from climatic context and individual analyses to comparative synthesis and recommendation. This supports the value of early-stage simulation in architectural education, where environmental feedback can inform decisions about massing, orientation, facade exposure, and passive performance before design choices become fixed (Li & Hong, 2020; Bernett et al., 2021; Rizaoglu & Voss, 2020). At the same time, the results show that access to simulation outputs alone is not sufficient. Students needed a structured comparative synthesis to transform visual evidence into design judgment. In this sense, the pedagogical value of the activity depended not only on the software, but also on the instructional sequence that required students to compare variables, identify trade-offs, and justify a recommendation.

The second objective addressed the role of collaborative real-time modeling. The shared cloud model appeared to support a form of spatial awareness that is difficult to achieve in conventional divide-and-compile workflows. Students could see how individual housing prototypes contributed to the larger residential system, including the relationship between lot position, adjacent volumes, open areas, and environmental exposure. This finding is consistent with literature on cloud-based BIM and collaborative learning, which emphasizes shared models, common data environments, and team-based coordination as mechanisms for developing professional collaboration skills (Basson & Smallwood, 2026; Hemmerling & Maris, 2020; Chenah & Boton, 2026; Herrera et al., 2018). In this case, collaboration was not limited to file sharing or model coordination; it became part of the environmental reasoning process because each student's modeling decisions affected the collective analytical context.

The third objective focused on how students translated environmental analyses into prototype recommendations. The comparative matrices and narrative syntheses were central to this process. They required students to weigh solar-hours performance, wind access, glare potential, and shadow behavior rather than selecting a prototype based on a single favorable condition. This is pedagogically relevant because bioclimatic design often involves trade-offs: a facade may receive useful winter sun but also require glare control; a corner lot may support ventilation but increase exposure; shadow may protect outdoor spaces in summer while limiting useful solar access in winter. The comparative synthesis therefore functioned as a bridge between simulation output and design argumentation, supporting the kind of evidence-based reasoning that sustainable design education seeks to develop (Altan et al., 2016; Cillari et al., 2021; Mashruwala & Jadav, 2023).

A notable finding was that not all environmental outputs were equally easy for students to interpret. The qualitative coding showed that interpretation difficulty appeared in 10 of the 19 reflections and was not limited to glare potential. Students also reported challenges when interpreting shadows, wind behavior, graphic scales, ranges, and the relationship among multiple variables. This finding reinforces the need to teach not only how to run simulations, but also how to interpret their assumptions, units, visual codes, and design implications. In this sense, interpretation difficulty was not a weakness of the exercise; it revealed an important learning threshold in environmental design education.

This interpretive difficulty also suggests a future direction for integrating generative artificial intelligence (GenAI) into environmental design education. Rather than using GenAI systems to generate design answers or select the best-performing prototype, large language models (LLMs) could be explored as a form of guided interpretive support to help students understand simulation outputs. For example, a GenAI-supported tutor could prompt students to examine legends, units, thresholds, visual patterns, and cross-variable trade-offs before making a design recommendation. In this role, GenAI would not replace environmental reasoning; instead, it would help students move from visual outputs toward evidence-based interpretation and self-justified design decisions.

The fourth objective concerned the advantages and limitations of different modeling workflows. The results suggest that Autodesk Forma Site Design was valued primarily as a visual, integrated, and rapid platform for early-stage environmental interpretation. Several reflections described the platform as useful because it allowed students to visualize solar exposure, shadows, wind behavior, and daylight-related outputs in one place. A smaller subset of reflections explicitly compared Forma with Revit or previous workflows, suggesting a perceived trade-off between modeling precision and analytical immediacy. Revit or previous tools were associated with greater familiarity or modeling precision, while Forma was associated with integrated analysis, visual feedback, and early-stage decision support. Because this theme appeared in only a subset of reflections, the workflow comparison should be interpreted as exploratory rather than as a definitive evaluation of Revit mass imports versus native Forma modeling.

The reflective evidence further suggests that students perceived a shift from intuitive reasoning toward more data-grounded design thinking. The coding showed that data-grounded environmental reasoning appeared in all 19 reflections, while multi-criteria synthesis or trade-off reasoning appeared in 17. Students began to describe orientation, wind access, shadow behavior, facade exposure, lot position, and climatic conditions through specific environmental evidence rather than general assumptions. This finding should be interpreted carefully because the study did not include a pre/post test, a control group, or a validated quantitative learning instrument. Nevertheless, the reflections provide useful exploratory evidence of how students understood their own learning process, especially when combined with the analytical artifacts produced in the Forma Boards.

The student-derived scores also require careful interpretation. They were useful for documenting how each team synthesized solar hours, wind performance, glare potential, and shadow behavior within its assigned zone. However, they should not be understood as standardized performance metrics or direct cross-team rankings. In one case, the score was normalized from a narrative comparative assessment rather than a complete numerical matrix. This reinforces the exploratory character of the study and suggests that future implementations should provide a more standardized scoring template if the goal is to compare prototype performance more systematically.

Overall, the case suggests that Autodesk Forma Site Design can serve as more than a visualization tool in architectural education. When embedded in a structured pedagogical sequence, it can support environmental analysis, collaborative model production, comparative prototype evaluation, and reflective learning. The main pedagogical implication is that cloud-native environmental analysis platforms should not be introduced as stand-alone software exercises. Their value increases when students are required to compare alternatives, justify trade-offs, and connect simulation results to design decisions.

The findings remain limited by the exploratory nature of the study. The sample included 19 students from a single undergraduate course at one institution, and the intervention lasted only two five-hour sessions. The reflective coding was conducted by the author as instructor-researcher and did not include inter-rater validation. The student-derived scores were useful for documenting comparative reasoning within each assigned zone, but they should not be interpreted as standardized environmental performance metrics or as direct cross-team rankings. Future studies should incorporate pre/post instruments, external rubric-based evaluation, inter-rater validation, or comparison groups to more objectively measure changes in environmental reasoning and design learning.

5. Conclusion

This exploratory case study suggests that Autodesk Forma Site Design can support early-stage bioclimatic site analysis in undergraduate architectural education when embedded in a structured, practice-based learning sequence. Within two five-hour sessions, students with limited prior exposure to the platform produced environmental analyses of a real residential development, including solar-hours, wind, glare-potential, and shadow studies. The nine-panel Forma Board structure helped guide students from environmental data collection toward comparative prototype evaluation and evidence-based design recommendations.

The findings indicate that the pedagogical value of Autodesk Forma Site Design lies not only in its embedded environmental analysis tools, but also in its capacity to connect simulation, collaboration, and design reasoning within a shared cloud model. The real-time assembly of the residential site allowed students to understand their assigned prototypes as part of a larger urban and environmental system. At the same time, the comparative prototype matrices and narrative syntheses encouraged students to consider multiple environmental variables rather than rely on a single performance criterion.

The qualitative coding of individual reflections suggested that students perceived a shift from intuitive assumptions about climate, orientation, and passive design toward more data-grounded environmental reasoning. Data-grounded reasoning appeared across all 19 reflections, while multi-criteria synthesis appeared in most responses. These reflective findings, together with the submitted Forma Boards and prototype recommendations, suggest that the activity supported environmental visualization, comparative prototype evaluation, and collaborative interpretation.

The workflow evidence should be interpreted more cautiously. Autodesk Forma Site Design was valued by students as a visual, integrated, and rapid platform for early-stage environmental interpretation. A smaller subset of reflections compared Forma with Revit or previous workflows, suggesting a perceived trade-off between modeling precision and analytical immediacy. Therefore, the study does not establish one workflow as superior; rather, it suggests that different modeling approaches may serve different pedagogical purposes depending on whether the emphasis is placed on geometric control, rapid testing, or environmental interpretation.

Several limitations must be acknowledged. The study was conducted with a small sample of 19 students in a single undergraduate BIM elective course at one institution. It did not include a control group, a pre/post test, or a validated quantitative instrument to measure learning gains. The reflective coding was conducted by the author as instructor-researcher and did not include inter-rater validation. The student-derived scores reported in Table 2 reflect comparative reasoning within each team's assigned zone and should not be interpreted as standardized environmental performance metrics or direct cross-team rankings. In one case, the score was normalized from a narrative comparative assessment rather than a complete numerical matrix.

Future work should examine whether the forms of environmental reasoning documented in this case transfer to subsequent design studio projects, particularly regarding students' spontaneous use of orientation, shading, wind access, and passive design strategies during early design stages. Further studies could compare Autodesk Forma Site Design with other environmental analysis workflows and incorporate standardized scoring templates, external rubric-based assessment, pre/post instruments, inter-rater validation, or comparison groups to measure changes in students' bioclimatic reasoning more objectively. Another promising direction is the use of GenAI, particularly LLM-based tutors, as guided interpretive support for environmental simulation outputs. Rather than providing design solutions, these tools could prompt students to examine units, thresholds, visual patterns, and cross-variable trade-offs, strengthening their ability to reason independently from simulation data.

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8. Declaration of Generative AI

Artificial intelligence tools were used for manuscript drafting and editorial revision. All content was reviewed, verified, and approved by the author.

9. Conflicts of interest

None

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