Go Big or Stay Home? Structural Understanding Through the Accessibility of Precedent

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Abstract

Use of precedents when teaching structural concepts to architecture students is one way to illustrate complex structural behavior but may not be understood in all contexts. While the internet allows for many well documented buildings across the world to be studied through photos, their structural performance may be less clear to architecture students who can benefit from experiencing a building in person. In response, this research considers how students' understanding of structural behavior compares between the study of well-documented, non-local precedents and the study of local precedents that students can visit. Through a project assigned in an architectural structures class that required the students to build a structurally functional model of an existing building, the affordances of precedents in teaching structures are considered and the level of student understanding is reported.

Introduction

The use of precedent to understand structural behavior in architectural design is valuable for student learning. While the advantages of precedent in architecture design are well discussed[1,2,3,4], comparisons of precedents available to students online versus in-person are less thoroughly considered. Visiting a precedent in person allows for a designer to experience a space and document the building themselves[3], suggesting improved learning. However, when examining the structural behavior of a precedent, it is less clear if the same principles apply.

In response, this research uses a precedent-focused assignment in an architectural structures course to examine how students' understanding of structural behavior varies between when the students could visit their assigned precedent and when they relied exclusively on online sources. The assignment was part of an architectural structures course at [university redacted for review]. The architecture program at [university redacted for review] emphasizes regional awareness in design and supports assignments that integrate local precedents in learning examples. However, examples of profound structural behavior local to the university are not as prolific as ones found through reputable online sources, such as archdaily.com[5]. Therefore, there is a tradeoff between benefits of documenting a precedent in person versus studying a precedent of exemplary structural expression. However, in developing the assignment, the possibility that the locality of a precedent may not support student understanding was considered. If students did not visit the local precedent or if they could not visually access all primary spaces of the structure, the location of the project would not matter. Student skillset and effort may also vary, resulting in difference of understanding regardless of precedent. This paper considers how locality of precedent may influence student understanding of structural behavior and makes recommendations for how to bolster student learning when assigning precedent studies in structures focused classes.

Background

Precedents in structural education

The use of physical models to illustrate structural behavior has been used by many educators. In "The Art of Construction: Projects and Principles for Beginning Engineers & Architects," Mario Salvadori[6] uses examples with regularly found materials, like paper and string, to illustrate structural behavior and prompt activities for the student readers. In "Model Perspectives: Structure Architecture, and Culture" Mark Cruvellier et al.[7] use detailed models of buildings located all around the world to connect structural form to architectural design objectives. Functional models can bend, deflect, and fail similar to their full-scale precedent. However, not all precedents illustrate the same concept when used as a learning tool.

While there are benefits to using existing buildings in structures education, the results (both beneficial and ineffective) of using precedents in the teaching of structures is less well documented in pedagogical research. MacNamara[8] used a project that involved historic precedents to teach structural behavior for many years. In the project, students completed a graphical analysis of a precedent, illustrating the forces acting on the structure and calculating approximate reaction forces. After many years of assigning this project, MacNamara sent a survey to current and past students to collect feedback about how they enjoyed the project. The general response indicated that students highly enjoyed the project. They reported that they learned a lot from the project by studying a precedent directly and applying concepts from class. The surveys were useful in affirming that the students enjoyed the project, but did not identify what specific aspects of the assignment supported or hindered student learning. In another paper, Chilton[9] reported on his observations from assigning students with a project that required students to build a model of a precedent. While Chilton states that their students learned from the project and provides several examples of effective student projects, Chilton does not explain when students make ineffective models, and he does not critically examine potential issues with the assignment. To better understand how precedents can support architectural structures education, it is useful to identify what attributes of precedents help in teaching characteristics of buildings.

Affordances of precedents

While there are many advantages and reasons architects employ precedents in design, this research focuses on three benefits of precedents because of their relationship to learning new ideas. The key affordances of precedents for this pedagogical investigation are autodidactic knowledge gaining, idea application, and expression of understanding, summarized in figure 1.

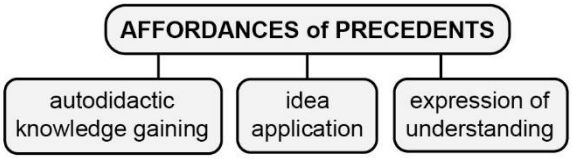

Fig. 1. The affordances of precedents as assignments.

The study of a precedent allows for *autodidactic knowledge gaining* when a student carefully examines a building to deepen their own understanding. Rather than a student being told an idea from a precedent in a lecture, by studying a precedent on their own, students can learn the idea through their own explorations, expanding their personal knowledge gaining[10]. This pedagogical approach is also evident in Project Based Learning in which students make conceptual connections on their own, leading to deeper understanding[11]. In addition, some educators reflect that the use of precedent in architecture may be beneficial to the education of engineers as well[12], suggesting that they are useful in teaching about structures as well.

Studying a precedent also extends a concept beyond a theoretical explanation to realistic application. The

application of ideas is another affordance of precedents in which students see how design decisions impact the built environment. Exploring existing examples has also been shown to be useful in the idea generation of building designs[3]. Mahmoodi[13] points out that the use of precedent-based knowledge can save time, effort, and resources by allowing a designer to borrow some features from the precedent and enhance new design solutions. While precedents may negatively impact creativity[13], there is also evidence that learning from precedents benefits the learning outcomes[1].

Expression of understanding is the third affordance that considers in what ways producing new artifacts from a precedent study reflects how an individual comprehends the precedent. While studying a precedent is beneficial, the act of expressing one's understanding is important as it allows for external validation of knowledge.

Methods

The class

This assignment was employed in the first of a two-class structures sequence. The majority of students were in their first semester of their third year of architecture and this was their first class that discusses structural behavior. The class is also cross-listed to include 3-year M.Arch students taking their first structures class. Approximately 68 students were 3rd year architecture UG students, 6 were 1st year Masters students, and 5 were either retaking the class as an UG or taking the class for another reason.

The assignment

Working in teams of three, Students were tasked to investigate an assigned precedent for its structural behavior, build a model that structurally worked like the precedent, and make a poster that captured additional characteristics of the structure. For the model, emphasis was placed on building a *functional* model, not one that just looked like the precedent. For example, the students were instructed to accurately show the assembly of structural members and decks, ensure that tension cables act in tension and compression members act in compression, and construct movable pin joints when/if they occur in the precedent. The models did not need to be built to scale. Students also made a poster that supplemented the model by showing full photos of the precedent and presented information not captured in the model including a force diagram that students could generate by drawing a free-body diagram or drawing on top of a photo of the precedent. Students were provided with a rubric that described a breakdown of the project's expectations, and they were prompted with several deliverable check points throughout the project's timeline to receive feedback on the development of their project. The students had 9 weeks to work on the project.

The *precedents*

Ten of the projects were located within a 2-hour driving distance of the city of the university and were not well documented online, while nineteen precedents were located more broadly and are well documented in online resources. Students worked in teams of three and could pick their teammates and their precedent. Nineteen teams chose this option. The other ten deferred their decision and were assigned to a team and precedent randomly. Table 1 lists the projects and their locality. It also indicates which project students choose, and which were randomly assigned.

Table. 1. List of precedents.

Local Precedent	Selected/Assigned
L1. Highland Pool	Assigned
L2. Walking Bridge at Copper & Tramway	Selected*†
L3. Rio Rancho Campus Park	Selected*
L4. Rio Rancho Public Library	Selected
L5. Santa Fe Opera House	Selected
L6. Entrance to the PIT	Selected
L7. Al Hurricane Pavilion	Assigned
L8. Los Altos Pool	Selected
L9. West Mesa Aquatic Center	Selected*
L10. St Michael and All Angels Church	Assigned
Non-local Precedent	**Selected/Assigned**
N1. Denver International Airport	Selected
N2. Curved Girder Bridge Neckartenzlingen	Selected
N3. Millénaire Footbridge	Selected*†
N4. Sean Collier Monument	Selected
N5. The Zarzuela Hippodrome	Assigned
N6. Circuit of the Americas, seat cover	Assigned
N7. Circuit of the Americas, tower	Selected
N8. High Line - Moynihan Connector	Selected
N9. Hangzhou Riverfront Public Space	Selected
N10. Beijing Shangzhuang Organic Farm	Selected*
N11. House of Chickens	Selected
N12. Gustave Flaubert Bridge	Assigned
N13. Fire Station in Houten	Assigned
N14. Vlooyberg Tower	Selected
N15. Millennium Dome	Assigned
N16. Tent House	Assigned
N17. Jardin San Hipólito	Assigned
N18. Brazilian Pavilion Expo Dubai	Selected
N19. Equestrian Center in Luxelakes Eco-City	Selected

*Two member selected the precedent before deadline and one teammate was assigned.
†The graduate students asked to be combined into one group of six. They were assigned two projects that they could compare.

Assessment method

While many metrics could be used to evaluate the projects, this paper focuses on the affordances of studying precedents and their value in structural understanding. The intent of the assignment is to help prompt students to identify details and themes in structural behavior within precedent structures, particularly ones mentioned throughout the course, and recreate them at a smaller physical scale. Therefore, the projects are evaluated through several streams of information, responding to the affordances of precedents. These evaluations do not include or reflect the students' grades on the project and their grade privacy is not violated in this report.

Acuteness of Model. This criterion assesses the autodidactic knowledge gaining of the students. The projects are divided into five categories of Acuteness of Model that reflect how closely the model behaved like the precedent. The five categories of this criteria are: I. Insufficient – The model does not, in any way, act like the precedent and it shows no understanding of the precedent; II. Low – The model hints at the precedent and reflects an attempt at understanding but does not behave like the precedent; III. Mid – The model shows some structural behavior but ignores significant attributes of the precedent, the students did not thoroughly study the precedent; IV High – The model exhibits the behavior of the precedent with minor opportunity for improvement, for example, the model uses representative rather than functional elements (such as using strings to indicate a tension member, but not actually pulling them taught in tension) or the model has correct structural behavior with small inaccuracies; V Exceptional – The model accurately and thoroughly functions like the precedent showing an extensive study and understanding of the precedent. Figure 2 shows a project model that aligns with each of the criteria. Interpreting the models is subjective, but this process provides an initial method for assessing model functionality. It is valuable to discern that a model can act like the precedent without an extensive amount of detail. While detail models were encouraged, a functional model can still show clear understanding of structural behavior.

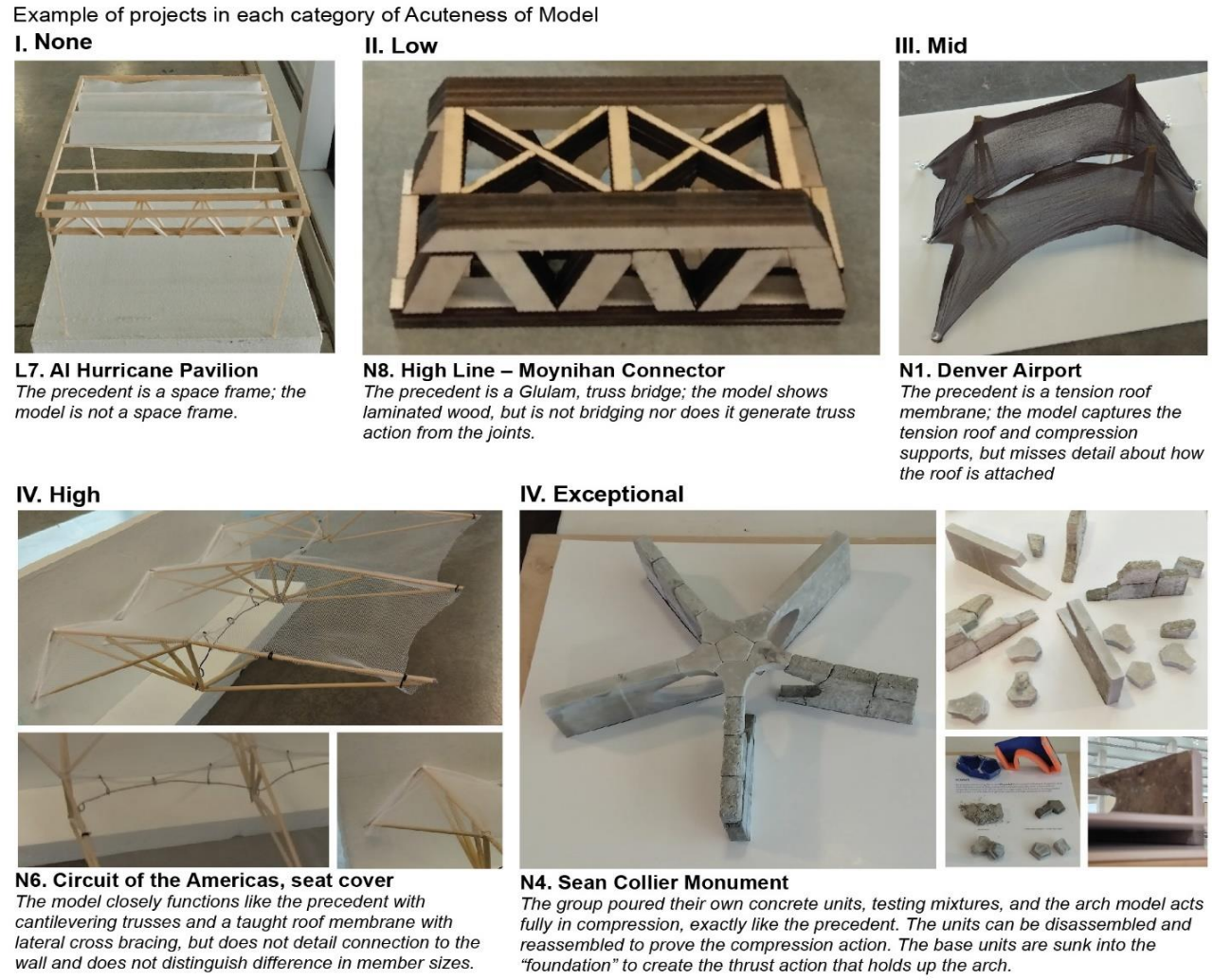

Fig 2. Examples of models in each of the Acuteness of Model categories

Force Diagram. The project rubric included several explicit criteria for the posters including a Force Diagram indicating how the structure directed forces to the ground. As the precedents varied in material and scale, the students were allowed to express the diagram by drawing their own free-body diagram of the precedent or drawing on top of a photo of the precedent. They were prompted to use their graphic skills to best communicate the structural behavior of the precedent. The complexity of possible diagrams varies by project and, as a result, their evaluations are simplified into 3 categories: I. None – This category indicates that the students did not include a Force Diagram on their poster; II. Attempted – The poster has a diagram that attempts to show a structural idea but is not quite accurate and could be improved; III. Correct – The poster has a diagram that is clear and the students correctly labeled and traced forces to the ground.

Craft of Submission: This criteria reflects the students' expressions of understanding by assessing the representation of the precedent on the poster and the craft of the model. A student may well understand a precedent's structural behavior, but being able to communicate their understanding is also important. Representing understanding is valuable as a designer and is an affordance of studying a precedent in which a representation can be right or wrong. Evaluating this criterion, however, is reflective of all architecture

education and not just within the purview of the structures class. Therefore, this criterion will not be categorized in this investigation. The Craft of the Submission will be discussed as a supplement to the other two criteria.

As an additional consideration, whether the local precedent teams visited their building in-person is noted. This was not a requirement, but lightly prompted. Students were asked if they visted the site, but their answers were also verified by checking if the poster contained images not found online indicating that the team visited the site and took their own photos.

Results

The projects are compared by category distribution within each group of local versus non-local precedents. The projects are also examined by grouping of selected v assigned precedents.

Local v non-local

Figure 3 shows a summary of the number of projects in each category for the acuteness of the model and the Force Diagram. For the local projects, five of ten projects were categorized as high understanding and the majority of those teams attempted a Force Diagram. For the non-local projects, the majority of the projects were categorized as either mid or high for the Acuteness of Model while ten out of nineteen attempted a diagram. While it is the aspiration of the learning outcomes that all projects achieve exceptional categorization, a normal distribution around projects being “high” is reasonable for project grades and is interpreted as a general positive reflection of student understanding from the project, but not dependent on locality of precedent.

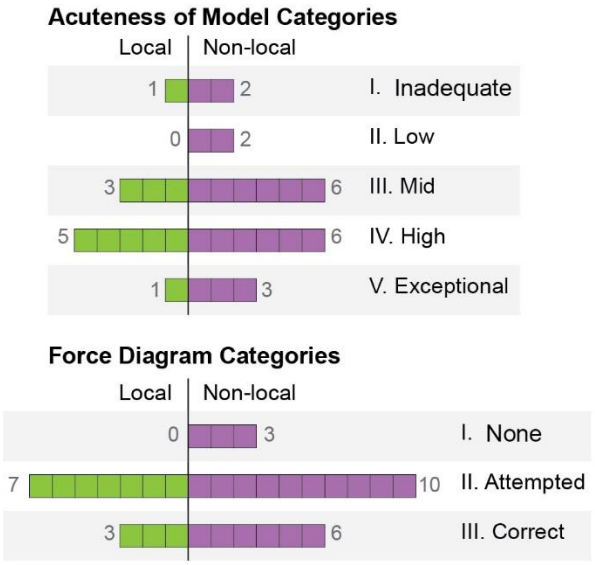

Fig. 3. Comparison of local to non-local project categories.

Selected v Assigned

As differences in local v non-local precedents were not observed from the categories, this research also compared the projects that were selected to the ones that were assigned. Figure 4 shows the number of selected and assigned precedents in each category. Again, a majority of both the selected and assigned precedents were in either the mid or high categories for Acuteness of Model and they attempted competent Force Diagrams.

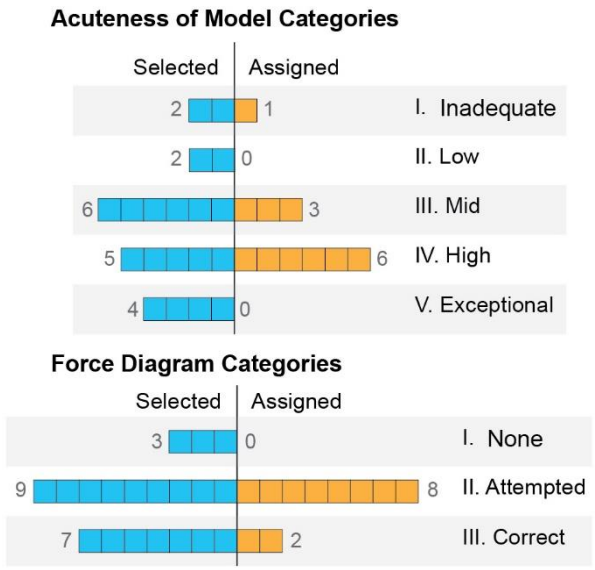

Fig. 4. Comparison of selected to assigned project categories.

Visiting the precedent

Of the ten local projects, six of the teams visited their precedent and four did not. One of the groups that did not visit their precedent reported that they tried to visit it, but it was closed for the season and not accessible. Table 2 lists the precedent, if it was visited, its categories of evaluation, and if it was selected by the team. While project L7 did not visit their assigned precedent and were categorized in the lower performing categories for their model and diagram, L2 also did not visit their precedent either and excelled in their model and diagram.

Table 2. Visitation and categories of local precedents.

Prec.	Visited?	Model	Diagram	Selected?
L1.	Yes	IV	I	Assigned
L2.	No	V	II	Selected
L3.	Yes	IV	I	Selected
L4.	Yes	IV	II	Selected
L5.	No	III	I	Selected
L6.	Yes	IV	I	Selected
L7.	No	I	I	Assigned
L8.	No	III	I	Selected
L9.	Yes	III	I	Selected
L10.	Yes	IV	II	Assigned

Discussion

From initial inspection of the categories, the locality of the projects did not influence the project's final structural understanding nor did whether the students picked their own precedent. There are several possible considerations for this outcome which can inform changes to the assignment in future semesters:

As the world becomes more dependent on digital forms of information, **the benefits of visiting a precedent in person may not be as valuable as viewing them online, at least not for structural understanding purposes**. When high quality photographs posted online provide details and clear depictions of materials, along with the architect's drawings of the projects, the information online may exceed what a student can understand in person. It was surprising that not all of the local project teams visited their precedent. This may be a reflection of how the school's architecture program is underpreparing their students to go out and explore the architecture around them, however, it may be that the students resisted activity not explicitly required of them, particularly if they could get low-quality information online.

It is also observed that individual **student skillset characteristics may play a larger role in the students' understanding than details of the assignment**. The students collaborated in teams of three to work on the project that had three parts: a model, a diagram, and a poster. The teams were encouraged to work together on all parts, but they may have divided up responsibilities, each creating one of the deliverables. As a result, students' individual skillset and efforts may more closely align with their project's quality and category assessment. For example, not all projects in category V. Excellent for Acuteness of Model aligned with category II Correct Force Diagrams as different students may have worked on the different parts of the project. While this theory is plausible in all group projects, regardless of

discipline, it emphasizes that individual projects, rather than group work, would benefit structures understanding and future projects should be assigned individually.

The models that were determined to be category 1 Inadequate may also have resulted from gaps in the students' understanding of the assignment and **some students require more extensive directive**. While the purpose of the project was repeated multiple times in class and the students were prompted to discuss their model ideas with the instructor, much of the onus was on the students to find information and ask questions when they were unsure of what to do for their individual precedent. As students were in at least their third year of architecture school, they were expected to take responsibility for their learning. It was also surprising when students did not visit the local precedents in person and this lack of initiative may indicate other areas of concern in architecture education to be explored in future research. In addition, creativity of construction and self-initiated exploration was encouraged to strengthen their skills as designers. However, the students that worked on these projects may have needed more direction as many of the structural concepts were introduced to them in the same class. While some students could excel with little instruction, a portion of architecture structures students may benefit from more assistance.

Limitations

The projects included in this paper are from one semester at one institution and may not represent the outcomes of all possible architectural structures students. The assessments are also subjective to the author's (who was also the instructor) interpretation of the models and diagrams. While the instructor has extensive background in both architecture and engineering, able to judge structural behavior confidently, further evaluation of the projects by other evaluators would deepen the results. Regardless, this report suggests a way to categorize precedent structural projects and considers what additional influences, besides precedent locality, may influence student understanding.

Conclusion

This paper presents the differences between projects that used local and non-local precedents for comprehension of structural ideas. When considering student learning of structural concepts, the affordances of precedents as teaching tools are useful in evaluating their efficacy on student understanding. The results from this research are useful for educators when employing accessible precedents in architectural courses and supporting improved structural learning.

Notes:

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