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**A facilitated learning environment to support  
the simulation of the collaborative design  
process in architecture**

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### ABSTRACT

Building design, construction and management, as a whole involve the largest number of employees, imply the most diversified set of professional profiles, waste more than half of total energy consumption, produce a major environmental impact, have a very large economical effect on other industrial sectors. As a consequence, building is a very complex industrial system that is performed through a very complex process. It consists of a collective, finalized and time-constrained process, scheduled by phases, made up by several actors, characterized by the co-presence of numerous and very different specialist skills (Carrara, Fioravanti 2002).

'Collaboration is an important aspect of the architects' education.' (Kalay, Jeong 2001). The teaching of architectural design is facing with increasing urgency those aspects of the pedagogy related to the collaboration within the learning activity. The work described in this paper is the result of our research on explorative, heuristic and simulative models: *Arch132* is, as well, in continuity with numerous exercises that have been experienced at UC Berkeley since the late 1970s for introducing students to the collaborative dimension of the architectural design, i.e. Cardboard City (Treib c. 1980) *Archville* (Peri 2001), *CADville* (2002), *Cube-Game* (Kalay, Jeong 2005).

*Arch132* is intended as a new technological tutoring support to facilitate the students while they exercise in a common design experience. We defined a web-based working environment and we developed a mechanism that automatize some design operations. It enables the students to a *real time interactive communication* allowing them to a critical exploration of the relationships between different individual contributions and assisting them in the process of constructing a shared and participative project. The idea is that students will be assigned a plot of land in the site. They will be able to see it in *Google Earth*. They will then import their site to *SketchUp*, and design a house. They will be able to export their house to *Google Earth*, where everyone can see it (all other students in the course). This can be done multiple times, so they can see what their neighbours are building.

Each student's last-updated work will be always visible to other students, eliminating the problem of making design decisions based on obsolete information. This exercise can help them to perceive the impact of decisions made by others on their own designs, allowing them to familiarize themselves with the problems and the benefits of the collaboration.

## INTRODUCTION

The legacy of design as a problem solving activity has been to consider collaboration a problem of effective communication where massive amounts of data must be shared in real time among participants.

According to Carrara et Al. one of the most common problems that affects current professional collaboration regards reciprocal interaction during the design process: this is especially true when the practitioners share the overall goal (e.g. a common neighbourhood) and are called to manage simultaneous individual tasks (e.g. the design of a single building), they neglect the search of any alternative hypotheses to achieve the larger objectives of the project as a whole, since they would involve longer time or greater design costs.

In this terms, assuming parity of resources like time and cost, to enhance reciprocal interaction facilitates to experience a better collaboration. Switching from one perspective to another, from one level of knowledge to another, the participants, individually and collectively, can better explore the design solutions, increasing the possibilities that the final solution is a better one.

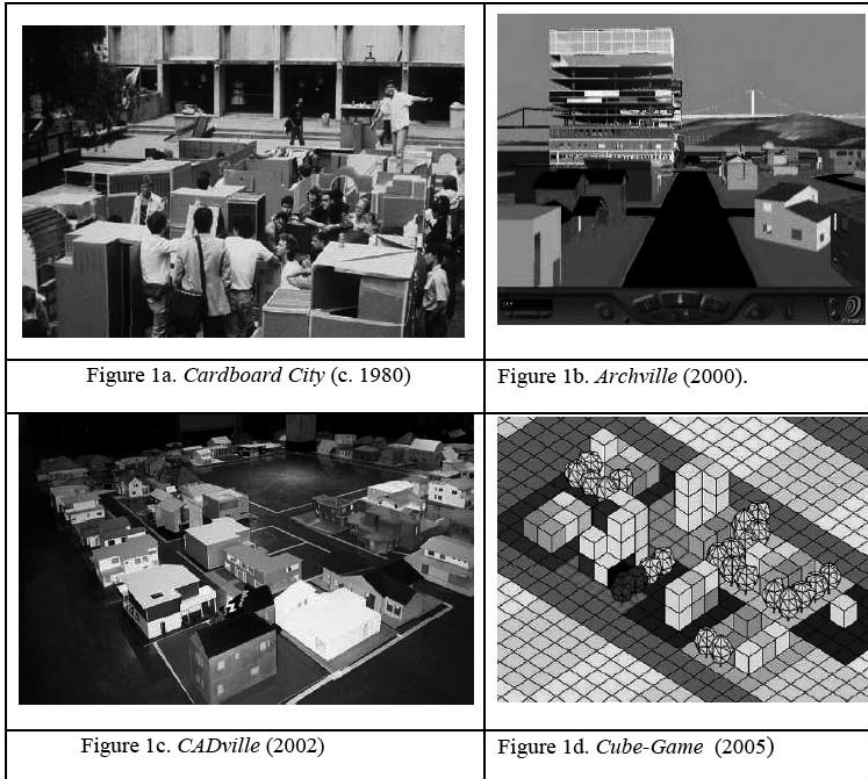
The teaching of architectural design is facing with increasing urgency those aspects of the pedagogy related to the collaboration within the learning activity: more and more learning to design means learning to conjugate the individual skills within a group, developing the ability for the critical analysis and mediation between our own objectives and the overall goal of the project on which we collaborate.

### State of the art

Attempts to introduce UC Berkeley students to the collaborative dimension of the architectural design process have begun in the late 1970s, through a comprehensive design exercise given to third year students directed by Architecture Professor Marc Treib. It was intended to teach them, among other things, how to deal with the creation of places as a *collaborative* form-making enterprise, rather than as an individualized effort. The exercise involved the design and physical construction of a *Cardboard City* (c. 1980) in a pre-designed 'urban landscape.' (Figure 1.a)

The advent of computing technology, in particular the Internet, resurrected the *Cardboard City* exercise in the late 1990s, using computer visualization in lieu of cardboard (Figure 2). *Archville*, as the new exercise was called, was pedagogically similar to the *Cardboard City* exercise (Peri 2001). As in the original exercise, each student was given a plot in an urban landscape. Instead of a physical space, *Archville* (2000) used a computer model of a hypothetical city. As in the *Cardboard City* exercise, students were asked to design their houses in agreement with their neighbors. Specifically, they were required to establish and agree upon some common design elements, such as style or color. Using VRML, *Archville* allowed students to 'walk' through the 'city' virtually (Figure 1.b).

A similar exercise followed two years after, when the virtual environment was substituted by a physical scale model of a city. Called *CADville* (2002), this exercise combined computer-aided design and physical scale modeling to create 80-100 houses that were located on scaled city plots. The students were asked to respect (actual) local zoning laws, existing structures and



**Figure 1a** Cardboard City (c. 1980)    **Figure 1b** Archville (2000).  
**Figure 1c** CADville (2002)    **Figure 1d** Cube-Game (2005)

morphologies, and coordinate their designs with other students in their immediate vicinity (Figure 1.c). But the students' preoccupation with their own designs, their reckless disregard of the design of fellow students, and the difficulty of (manually) enforcing collaboration, resulted in architectural chaos. While this outcome was appreciated by the students, and served to underscore the need for collaboration, it did little to help them actually experience it.

To overcome the students' natural tendency to focus on form-making, and to concentrate their efforts on the collaborative aspects of the design process, Kalay and Jeong have developed a simulation game called Cube-Game (2005) that provides a simplified framework within which a large number of students can experience the process of collaboration. In essence, it replaces complex form-making with simple colored cube-shaped 'rooms,' which the players must 'buy' or 'trade' with each other. Instead of intricately-crafted buildings, the game emphasizes the impact of actions taken by fellow 'designers' and the opportunistic nature of forming collaborations on the individual students' ability to accomplish their own goals (Figure 1.d).

## INNOVATION

Analyzing this previous experiences we learned two different kind of lessons that have driven our work: one hand all the exercises but the Cube Game didn't implement an effective real time interaction system between the distributed actors; on the other hand the Cube Game, in order to focus them on the collaborative process, avoids the architectural grammar as a mean to contribute at the product-based discussion, losing some of the playful appeal that engages the students of architecture. The ARCH132 environment supported by a technological tutoring system aims to be the place where the single design actors can experience and contribute to the collective exercise with their collaborative ideas and signs.

We defined a web-based working environment and developed a mechanism that automatize some design operations. It enables the students to a real time interactive communication allowing them to a critical exploration of the relationships between their individual contributions and assisting them in the process of constructing a shared and participative project. Each student's last-updated work will be always visible to other students, eliminating the problem of making design decisions based on obsolete information. At the same time this exercise can help them to perceive the impact of decisions made by others on their own designs, allowing them to familiarize themselves with the problems and the benefits of the collaboration.

## METHODS

### **Collaborative environment: PDW and SDW**

When the actors in a design process make decisions, they use their own private representations, knowledge, methods, and resources. At the same time, to be able to perceive other dimensions helps them to better understand their own. This experimental application of Information Technology to architectural design studio, is based on continuous, real time interactive exploration, from one perspective to another, from one level of knowledge to another.

Each designer alternates between their 'private' representations, used during their own, internal design process, and the 'public' version which they 'publish' for the benefit and use of the other participants. Moreover, much of this 'private' information is irrelevant and incomprehensible to other actors. By means of a product-process approach, according to Carrara and Fioravanti (Carrara-Fioravanti 02) we conceived the organization of the didactic collaborative environment dividing the 'Design Workspace' into a 'Private' one, specific to any operators, and a 'Shared' one, common to all of them; also we developed a web-based mechanism that allows real time interaction between the PDW and the SDW. Decisions taken in the 'shared design space' involve aspects that are typical of networked design and that are partially present in the 'private' design space.

The students opportunistically switching from one environment to another, more precisely from the private workspace to the shared one, have the technical opportunity to enforce their critical investigation and, more generally, their cognitive and productive abilities.

### ***How does it work (process – product approach)***

We assign to each participant enrolled in the course his own plot within a shared site where he



Figure 2 Visualization in Google Earth of the shared site

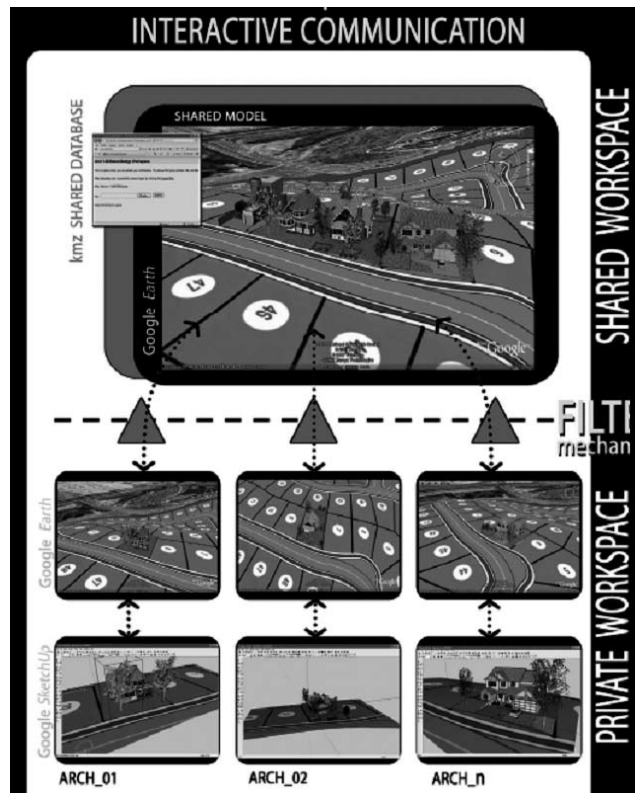


Figure 3 The filter allows students to visualize in real time what their neighbours are building

is called to design a single family house with a yard. Every student develops individually in his own Private Space his model which, in real-time can be visualized in the shared space together with his colleague's contributions. The work of collecting this individual contribution and replacing them on the geo-referenced common site is executed by an automatic mechanism. It manages the upload on the course web page enabling each student - every time he/she publishes new modifications - to the dynamic exploration of the updated shared model.

The procedure is: you enrol on the course Internet web page hosted on the University server. You then automatically receive your own plot number. Download from the server the collective file of the site and visualize it opening in Google Earth.

After the plot has been identified on the globe, that portion of terrain mesh has to be captured, exporting it as three-dimensional geo-referenced surface from Google Earth in Google Sketch-Up. At this point the work continues on the local pc Sketch Up environment in order to make your own contribution to be modelled and to be saved on your private hard-disk ( e.g. 09.skp).

Actually the program allows viewing this model on local pc, exporting it and placing it on the Google Earth environment. It is required to save this private view in order to be integrated with the other models (e.g. 09.kmz) .

Every time you want to visualize your project together with your colleagues' updated ones in the Google Earth shared site, you have to activate the filter mechanism. It recognizes you, checks for the login on the course web page, manages the upload of your model on the centralized server, merges it on a common file and, finally, it enables you to access the shared model updated view just by clicking a button.

Every time you want to experience the human scale visualization of the updated site in the Torque game-like environment, you have to export the model of your house from SKP to 3DS and DTS files and upload it on the server. At this point you can see other fellow students' avatar walking through the environment, and communicate with them by chat and e-mail.

### **Mechanism: Formats and protocols**

Google Earth is a tool to view virtual Earth through superimposing images obtained from multiple sources, such as satellite imagery, aerial photography, GIS data and three-dimensional geometries and search information about particular locations that draw interests. It uses an XML representation called KML (KeyHole Markup Language) for managing and manipulating its graphical and non-graphical data. Figure 4 is a glimpse of KML.

In this exercise, we prepared a web server for managing student account and generating a customized KML that collects all the latest works of the students. The server also has a repository that stores the students' works and keeps tracks of their interactions.

We used a simple mechanism to retain versions of the students' works in such a way that each student uploads a KMZ file (a compressed version of KML) of his/her design and the server gives a timestamp to the file.

```

<?xml version='1.0' encoding='utf-8'?>
<kml xmlns="http://earth.google.com/kml/2.1">
<Document>
  <name>Arch132</name>
  <Placemark>
    <name>Arch132</name>
    <LookAt>
      <latitude>37.76181691065554</latitude>
      <longitude>-121.909349519166</longitude>
      <altitude>367.2564660121528</altitude>
    </LookAt>
    <styleUrl>#default+nicon=http://maps.google.com/mapfil
al3/icon63.png+hicon=http://maps.google.com/mapfiles/kml/pal3
png</styleUrl>
    <Point>
      <coordinates>-
121.909349519166,37.76181691065554,0</coordinates>
    </Point>
  </Placemark>
  <NetworkLink>
    <name>l</name>
    <Link>
      <href>torturing1_exploded.kmz</href>
      <viewRefreshMode>onRegion</viewRefreshMode>
    </Link>
  </NetworkLink>
</Document>
</kml>

```

Figure 4

A typical part of KML

## Arch 132/Shared Design Workspace

This is a place where you can upload your contributions. The allowed file types are **kmz**, **3ds**, and **dts**.

After uploading yours successfully, please logout by clicking this [logout link](#)

Max. filesize = 104857600 bytes.

File :

Select the file(s) for uplcad.

### .kmz

Version (.kmz)	Date	File Name
7	Mon, 27 Aug 2007 21:14:33 PDT	<a href="#">house1.kmz</a>
6	Mon, 27 Aug 2007 21:12:53 PDT	<a href="#">St01.kmz</a>
5	Mon, 27 Aug 2007 21:09:37 PDT	<a href="#">house1.kmz</a>
4	Thu, 23 Aug 2007 10:55:12 PDT	<a href="#">16106945_57.kmz</a>
3	Thu, 23 Aug 2007 10:37:18 PDT	<a href="#">st01_57.kmz</a>
2	Tue, 21 Aug 2007 19:36:50 PDT	<a href="#">house1.kmz</a>
1	Mon, 13 Aug 2007 15:59:39 PDT	<a href="#">house1.kmz</a>

Click [here](#) to see all the other students' work

Figure 5

The public (shared) design workspace for the exercise

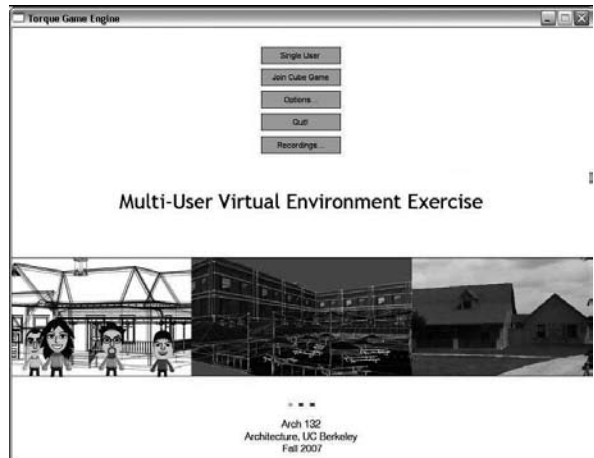


Figure 6

The multi-user virtual environment exercise



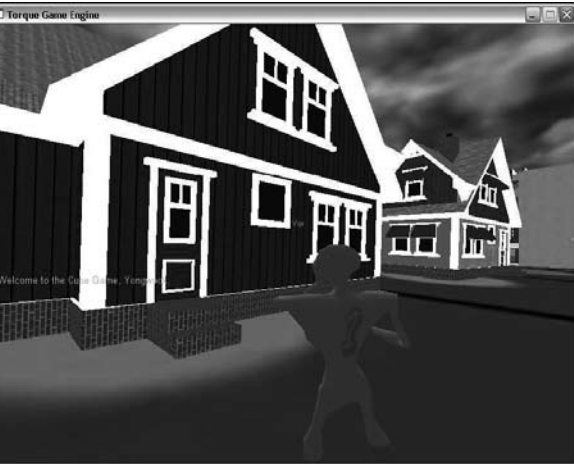


Figure 7 A user's appearance on his plot #9

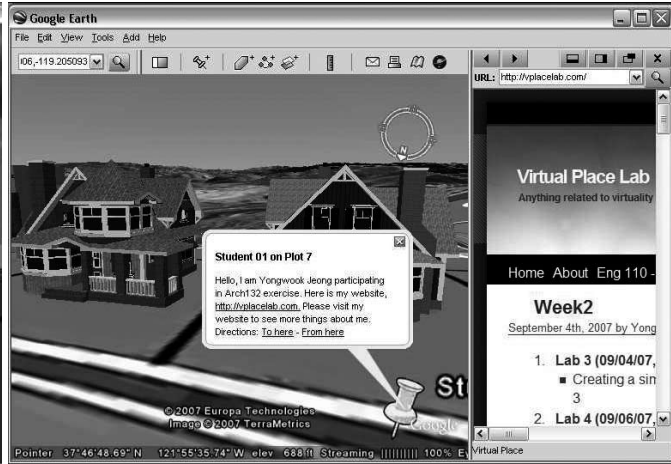


Figure 8 A placemark in Google Earth

As Figure 5 shows, whenever the students post their designs on the server, the server keeps all the versions that have been submitted by them while they still can see their previous works. In addition to KMZ, the server also handles 3DS format and DTS.

The main design tool for the students is Sketchup. Sketchup has a simple but intuitive interface to create polygon-based models. It closely ties with Google Earth in that Sketchup can export KMZ format by default and 3D Warehouse is the main shared repository where Sketchup users can upload and download their models. Sketchup also has a scripting language extension based on Ruby Programming Language.

We developed several plugins using the extension mainly for implementing the mechanism that is intended to facilitate in-publish and out-publish process.

Google Earth has excellent features to represent geographical data, but it lacks functions for the students look around their plots together with their neighbors while communicating with each other in real time. In order to facilitate this type of communication, we made a multi-user game-like environment using Torque Engine (Figure 6, 7). In the same way that the students upload their KMZ files, the students can post their 3DS and DTS files on the server. They are also managed in the same manner with KMZ files. We used 3DS and DTS format for the engine.

### Place-marker and link to personal web pages

We let the students have their placemarks on their houses or plots in Google Earth (Figure 8). The placemark mechanism in Google Earth is a way to present more description on a specific

location. As in Figure 8, the students can create their own placemarks in textual description that are automatically converted to HTML format.

If a user clicks available links in the callout box, a built-in browser will show up and lead to the link. Since they are supposed to have their own websites before this exercise, the students can obtain more information about others and eventually communicate with each other better.

### **Complexity and work organization**

Which Collaboration? Between Association and Team Work, toward Creative Collaboration. When the number of participants to a design activity exceeds a certain threshold, such as the project of a 100 houses' neighbourhood that we propose in this case of study, it becomes necessary to cope with the consequent increasing complexity. The management and integration of individual contributions then requires more effective forms of labour organization.

Based on the classification of Kalay (2004), three types of collaboration are intended to occur during the process.

1. Association is the simplest form of collaboration. It occurs when the students acknowledge that there are others working on the same geographical location albeit they have been assigned different individual plot. Their collaboration is relatively loose, imposing few mutual constraints on the participants. The students enjoy a relatively great degree of autonomy, since the actions of the individuals are largely independent of each other. "When irreconcilable conflicts arise, or when an individual ceases to enjoy the benefits of the association, s/he may leave the group, often with little consequences to the group itself (they can usually recruit someone else), or to the individual (s/he can join another group, or practice alone)".
2. Teamwork focuses on specialization of individuals from either one domain or multiple. Although we do not explicitly let the student make groups of two or more, we regard this exercise as teamwork among architects. Even if every plot has just one owner, we want them to realize the double nature of the responsibility they have: on one side it is explicitly related to their individual house, on the other it is related to the neighbourhood and shared with the whole class. Since the overall goal is a collective one, each student is implicitly part of a teamwork. Through the pipeline with Google Earth and Sketchup, the students will be able to consider their neighbors' design while they are designing on their private workspace (i.e., Sketchup with plugins) and the public workspace (i.e., Google Earth).
3. Creative collaboration occurs when two or more students decide to share their resources and combine their talents defining some shared guidelines or rules in pursuit of more elaborate houses in favor of their neighbors. "The input received from fellow collaborators may trigger new, innovative solutions, or combinations not seen earlier. In this case, collaboration becomes a process of shared creation, where the exchange of ideas among the participants helps to stimulate and enrich their own creativity, to the extent that the solution they arrive at is novel and unique."

## EXPECTED RESULTS

We contend that this collaborative environment can help the students by facilitating in real time the integrated visualization on SDW of the individual works developed on the PDW. The awareness of the relationships between each contribution and the overall design goal is thus improved.

Experiencing the project of a single family house within a collective neighbourhood, the student is supported for the exploration of the connections between his building, the neighbourhood, the entire site and the urban-landscape context of the intervention.

Simulating the integration of individual design solutions we intend to stimulate the designer's participation in the definition process of the shared scenario.

To be able to observe how our own choices can influence (suggest, contrast) someone else's and vice versa is one basic premise for the interaction: we want to guide and support the individual tasks focusing on the relations among them and with the overall solution.

The understanding of one's individual role inside a design group, develops a dialectic of comparison among the participants, orienting them to collaborate in the search for integrated solutions and in suggesting new ones, hopefully creative or just better than the ones they could reach working alone.

## DISCUSSION

Creative Collaboration starts when participants share some of the objects of the design: if they want to modify the configuration of some properties they necessarily have to confront their colleagues' choices and motivations.

In this simulation process we operate some simplifications: for instance, letting the students share exclusively the general place of intervention, they will enjoy for their individual projects a relatively great degree of autonomy. Moreover since the site is already defined in his general organization and doesn't allow overlapping of properties and responsibilities then the actions of the individuals are largely independent of each other. They can easily experience Association and Teamwork as forms of collaboration, but hardly get to the higher level of Creative Collaboration. On the other hand this kind of simplifications have two main positive results: referring to the product from an operational perspective, it facilitates the integrated visualization of the individual projects, and in doing so it increases the possibilities of defining common scenarios intended as a set of correlated events (Mechanism Sketch Up - Google Earth). In terms of process, the simplification enables carrying on a participative discussion on hypothetical desired scenarios, allowing to define strategies, intended as set of devised actions, during all the evolution of the design process. (Blog, Chat, Whiteboard).

This environment can provide a feel for the social dimension of collaboration, hopefully acknowledging toward a common overall goal, but it bases his contents communication side quite exclusively on implicit codes and syntax conventions that govern the technical drawing in the architectural domain.

## FUTURE WORK

Achieving interoperability among different CAD systems by way of organizing efficient databases is the core issue of our collaborative research. We aim to enhance the communicational aspects among designers, through the support of technologies able to translate and interpret the semantic content driven by the set of shared design objects.

The support of filtering mechanisms, intended as a collaborative key, becomes more precious and effective as it enables making explicit the information needed by each designer at the right moment during the design process.

## ACKNOWLEDGEMENTS

The authors wish to thank Prof. Gianfranco Carrara and Prof. Yehuda Kalay, who historically started and developed the collaborative research we are actually involved on. Sharing their experience and thoughts they offered the conditions to develop this exercise.

We also wish to thank the UC Berkeley students who will participate on Arch132 course and whose comments will help us to revise and refine it.

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