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A Case Study of Applied Co-Design in 3D Virtual Space for Facilitating Bicycle Use on Light Rail Systems

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Abstract

Cycling is highly recommended by experts concerned with environmental and public health. Cycling does not produce CO_2 emissions, can be economical, and can improve physical fitness. However, the barriers to cycling remain significant to many. Combined with a light rail system the bicycle offers a compelling alternative to automobiles; yet, bicycles are denied access on certain rail systems because they can take too much space away from pedestrians who share the light rail interior. To help solve this problem, Co-Design in 3D virtual space is proposed as an effective means of creating an innovative design solution.

The digital questionnaires and virtual 3D modeling research/design method used in this study gives the participant the ability to offer insights and express ideas through digital means and in 3D virtual space. This method, Co-Design in Virtual Space (CoDeViS), was developed by the author. CoDeViS methods are an outgrowth of physical co-design methods such as 2D collages and 3D Velcro modeling, developed by those featured in *The International Journal of CoCreation in Design and the Arts*. Physical 3D methods have been widely accepted in the new product development industry as effective ways to involve people outside a design team in the research and design process. CoDeViS methods offer promise to those seeking to make the principles of co-design available to larger groups of people in discrete locations around the world at lower cost. Historical developments, current technology, and the abilities of everyday people make CoDeViS possible.

Keywords

User-Centered Design; Design Research; Co-Design; Virtual Product Development

The goal of this project was to apply and test a 3D virtual co-design method to solving a sustainable commuting problem in the United States. Cycling has obvious benefits for the individual and society. Cycling does not produce CO_2 emissions, can be economical, and can improve physical fitness. However, the barriers to cycling remain significant to many. Combined with a light rail system the bicycle offers a compelling alternative to automobiles; yet, bicycles are denied access on certain rail systems because they can take too much space away from pedestrians who share interior space. To solve this problem, innovative design solutions may be needed. The case study in this paper describes how one problem in sustainable commuting may be addressed through Co-Design with potential end users.

Interest in light rail commuting systems is growing and seems to be effective; yet, using a bicycle in conjunction with light rail can be problematic. One problem for pedestrian use is that lines are not through all neighborhoods or close to all businesses and schools. Using a bike to go where the train cannot is a possible solution to this problem (and can make for a highly efficient commute) but current light rail train interiors are designed to accommodate a very limited amount of bicycles that are sometimes not allowed during peak operating hours. While light rail enables a cycling commute for many, barriers exist for the cyclist (and others with carts, baby strollers, or luggage) who would like to use light rail.

United States light rail systems in cities such as Houston, Texas and San Francisco, California ban bicycles completely or during peak operating hours. Peter Wang, a *Citizens Transportation Coalition* member in Houston said:

> "Bicycles get you quickly to and from the local rail station; rail takes you miles without personal effort. Combining bikes and light rail would therefore seem like a no brainer… But did you know that regular bicycles are currently banned from Houston's light rail trains during the all-important weekday commuter rush hour? Furthermore, only two bikes are allowed on per train car, which are as many as are allowed on the bus bike racks... and each rail car holds many more people than the bus. " (http://biketrain.blogspot.com/2007/11/help-get-bikes-on-houstons-light-rail.html, retrieved 4/1/2008).

Other cities that allow bicycles on light rail systems have limited space available, and the cyclist may not gain access to a train if trains are too crowded. This problem inspired the case study and of the application of the design research method contained in this paper.

This problem is addressed through a research and design approach of end-user involvement resulting in a viable concept. The digital correspondence and virtual 3D modeling research/design method used in the case study gives the participant the ability to offer insights and express their ideas through digital means and in 3D virtual space. This method, Co-Design in Virtual Space (CoDeViS), was developed by the author. CoDeViS methods are an outgrowth of physical co-design methods such as 2D collages and 3D Velcro modeling, developed by those featured in *The International Journal of CoCreation in Design and the Arts*. Physical 3D methods (e.g. Velcro modeling) have been widely accepted in the new product development industry as effective ways to involve people outside a design team in the research and design process.

CoDeViS methods offer promise to those seeking to make the principles of co-design available to larger groups of people in discrete locations around the world at lower cost; potentially facilitating both quantitative and qualitative research design. Additionally, those interested in design research are keenly aware of the need to minimize cost and increase the speed of product development. CoDeViS shows promise as an effective methodology to conduct design research and co-design on a large scale, with minimal cost, and at a speed that is compatible with the fast pace of product development. It also does not require highly developed technical skills beyond those possessed by typical industrial designers who have basic

competency in computer aided design. However, those that employ this approach do need to have at least an appreciation for design research and the potential creative input of participants (i.e. end-users and other stakeholders).

The Roots of Co-Design

It has been said that if design is problem solving, then design research is problem finding (Marty Gage, Lextant, personal interview, March 2008). The case study in this paper and with co-design in general, we think of the research participant as one who can both supply information about real world design problems and help solve those problems collaboratively with the designer. This concept of the participant is fairly new in the historical development of design research. Also, the notion of designers doing research has not always been popular and has only recently (within the last 18 years) gained widespread acceptance (Arnold, September 18-20, 2006).

Through the 1950s, research constituted a "straight-jacket" according to some industrial designers as described in a major article in *Industrial Design* magazine in 1958 (Fleishman 1958). Subsequently, in the 60's and 70's this kind of reaction to research persisted; some industrial designers felt rigorous "scientific" methods limited the creative and intuitive aspect of an industrial designer's activity and that research was, "a fancy way of telling him (the designer) something he already knows through long experience." (Fleishman 1958). Fleishman (1958) also confirms how some industrial designers were conducting research: "…it is their need to develop an exploratory, informal and even free wheeling approach to research – while remaining creative designers – that has conditioned them to maintain their amateur standing as researchers…The manner in which designers have fitted research to design is a reflection of their awareness of the limitations and dangers of over-formalized M/R (market research)." This "free wheeling" approach to design research, as Fleishman describes, has advantages that include direct designer contact with: context, activities, attitudes, beliefs, and generally larger contextual issues not revealed through typical quantitative market research provided (or missed) by an outside researcher or report.

However, over the last 50 years, a few industrial designers did not resist research. They promoted the activity among peers and with clients. A few examples include: Observation and personal interviews conducted by Henry Dreyfuss Associates (Dreyfuss 1955); designer participation and time motion studies conducted by designers for Montgomery Ward and the "pop tent" design (McCullough 1957, Ferebee 1959); and observation, interviews, and surveys by Byron Bloch for Stantham medical instruments (Kelly 1966). The designers who conducted research remained a minority until a process of reconciliation began to occur in the late 1970's and 80's when design firms began hiring social science research experts who shared their approach to research and helped formalize the design research process and methods. However, for the majority of industrial designers, indifference and even contempt toward research remained until about 18 years ago when the effects of social science expertise began to be felt in the industrial design community (Darrel Rhea, personal interview 9 November 2004). So, industrial

designers have, in a sense, "borrowed" traditional research methods used in the social sciences (e.g. observation and interviewing) and time compressed the typically long duration of an ethnographic field study to appropriately fit the demands of fast product development; these methods are also used in a more targeted way that reveal unmet user needs.

The inclusion of social science expertise helped formalize research in industrial design and has given credibility and added value to the research activities of industrial designers. Arnold Wasserman terms the result of this evolution of industrial design, and inclusion of formal research methods in the design process as, "research based design" (personal interview 29 December 2004). Research based industrial design has become standard practice with many industrial designers and in product development. Through the work of several key social scientists (e.g. Elizabeth B.-N Sanders at Richardson Smith/Fitch, Sonic Rim, and Make Tools), participatory Co-design methods are a current growth area in the field of design research used in industrial design. CoDeViS is a natural "next step" for Co-design; leveraging virtual space as a potential facilitator of fast paced, global, low cost, efficient, qualitative, and quantitative design research.

Co-Design Theory

CoDeViS is appropriate at the "fuzzy front end" of design or later in the design process. There are several ways collaboration can occur: file storage/transfer media (e.g. CD, USB drive), Intranet/Network, or internet/website. Basic tools include: a computer, 3D modeling software, and a word processing program.

Relying on the creativity of end-users during the design process is well founded. This has been done for years using physical methods and tools. Design firms such as Fitch, Sonic Rim, Make Tools, and Lextant have included everyday people in the research and design process as co-designers. One concept that helps us understand the potential value and basis of CoDeViS during concept generation is to understand the idea the above firms promote as "Make, Do, Say." This represents a spectrum of end-user participation methods in research and design (see table 1):

Say	e.g. Interview, Questionnaire, Discussion Group
Do	e.g. Observation, Usability Test, Video Ethnography
Make	e.g. Collage, Workbook, Velcro Modeling

Table 1, Say Do Make

Using this model, the design team can get a more complete understanding of the customer through what they talk about, how they act, and how they express their dreams through making things (Dresselhaus, 2000, p. 98-99; Sanders & William, 2001; Squires & Byrne 2002 p. 33-36).

Velcro Modeling in particular (see table 1) enables a participant to create actual forms that are abstract yet have physical dimensions that are concrete

without being heavy laden with specific sensory detail such as color, surface texture, exact dimensions, or other realistic representations that are more appropriately left to later in the design process when concepts or prototypes are being refined. The abstract and iconic nature of Velcro models allows enough room for the participant and others to envision the potential of the ideas that the participant/co-designer is trying to express (McCloud, 1994; Sanders & Williams, 2001). To a certain extent, modeling material is purposefully simple and abstract in order to encourage creative expression without being led toward preconceived solutions.

Before Velcro Modeling occurs there are usually immersive activities and tools that the participant co-designers engage in before making models. This usually entails journaling or workbook activities that help the participant to immerse themselves in their existing experience so they are prepared to deal with and express problems they are having or ideas they want to share when they create representations. Following this pattern, CoDeVis can also help participants express their creativity and dreams through virtual 3D space. The following case study involving the integration of bicycles and light rail serves to illustrate how this can work.

Case Study

Five adult volunteers were recruited to participate in a CoDeViS project to help accommodate people and bicycles on light rail. The participants were familiar with bicycle riding, public transportation in the United States, were students in the author's design class, and ranged in age from 20 to 23 years. One female and four males participated. None of the participants had any practical 3D computer modeling training or skill. Each was offered extra credit points to participate, was told that the work would involve "integrating bikes on trains," and that the study involved 3D computer modeling.

Without any training or instruction, each participant was given a compact disk with three files contained therein. Each participant then used approximately 2 hours of their free time during a one week period, outside of class, to complete the exercise. The files were the following:

- File #1 MS Word document that contained directions, a story, and a space to write in thoughts and answers to questions.

- File #2 Google SketchUp application (a 3D modeling application available at no cost, also downloadable from Google)

- File #3 SketchUp 3D model file containing a model of an empty light rail car and abstract shapes to use as virtual "Velcro modeling" parts (see figure 1 below). The models were created with minimal effort using "Rhino" NURBS 3D CAD software and exported as a .3ds model file (SketchUp imports this and other file types).

The MS Word file had directions beginning with an exercise designed to help the participants immerse themselves in the design problem prior to creating virtual 3D concepts:

> "*Begin by imagining that you live 30 miles away from work or school and that you want to avoid using an automobile for commuting. You may want to improve your physical fitness, save money, help the environment,*

or whatever other reason that you feel appropriate. The main problem is that riding your bike 30 miles takes too long for your schedule and the weather may occasionally be unsuitable for a bike ride over that distance.

Fortunately, your local government has decided to build a light rail system in your area making it possible for you to utilize it. One problem is that lines would not be through everyone's neighborhood or be close to all businesses and schools. Using a bike to go where the train cannot seems like a possible solution to this problem but current light rail train interiors are designed to accommodate only 2-4 bikes and bikes are usually not allowed during rush hours in other cities.

If you could design a light rail system that would accommodate more bikes, yet allow passengers to feel reasonably comfortable, what would it look like?"

The participants were then asked to fantasize about solutions and write at least one paragraph about ideas they had about an ideal experience where bicycles could more easily be accommodated on light rail.

After writing, the participants were then asked to install Google SketchUp on their own computer, familiarize themselves with it, and open the SketchUp 3D model file so that the ideas could be expressed in 3D (see figure 1 below).
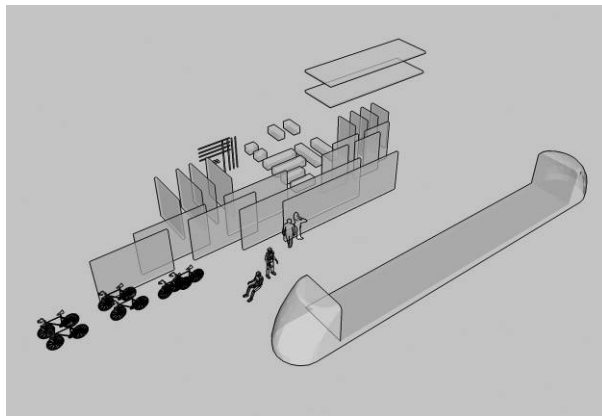

Fig. 1. SketchUp model file as it appeared when opened by participants.

Each participant then visualized their ideas by moving and placing the abstract shapes; which were subsequently assigned meaning and notated using the text tool included in SketchUp (see figure 2 below).

After completing the exercise, the participants placed their files in a web site "drop box" which were later downloaded by the author. A content analysis of the written portion of the participant response files was conducted. Reoccurring needs/desires were color coded and compared with other responses. Specific ideas were also identified in the text and compared with the SketchUp models. Participants offered several ideas in text form and modeled similar or other ideas in SketchUp. The participant model files are depicted in figure 2 below.
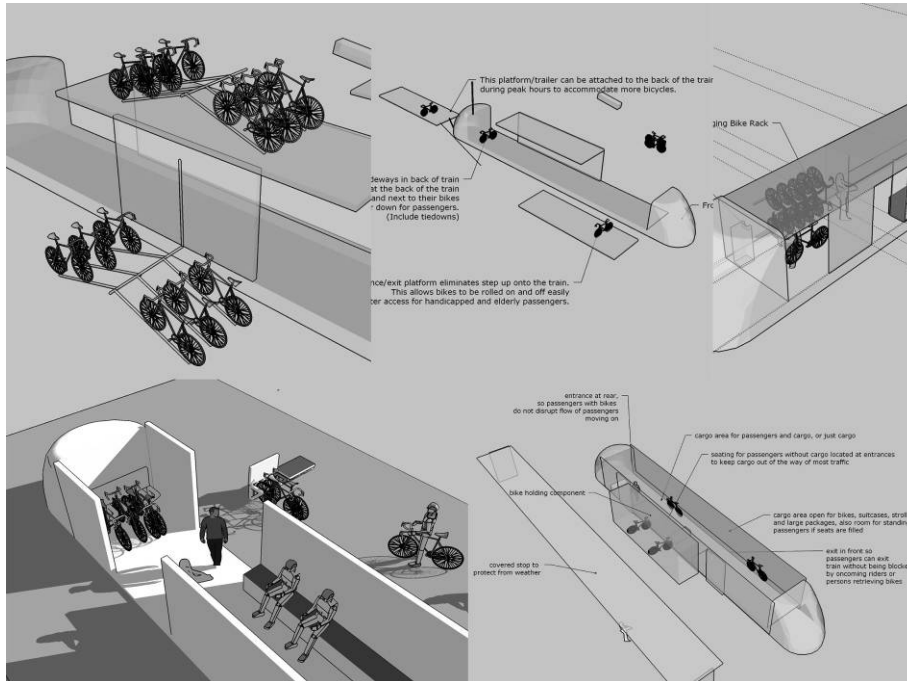
Fig. 2. Five Google SketchUp model files manipulated by the participants

The analysis of the written responses revealed several important issues. A feeling of security would be important to some of the users; sensitivity to ingress/egress was needed on the part of cyclists and pedestrians; close proximity of cyclist and cycle was desirable as well as a willingness to part company with it if it was carried in a secure location on the exterior of the train; and flexible seat/bike storage areas are needed. Surprisingly, thoughts about the train stop were also offered by two of the participants expressing that part of commuting experience would be enhanced by expanded facilities and information at the train stop such as vending, comfortable seating, restroom, other amenities, and information about arrivals/departures. As can be seen in figure 2 above, ideas were varied; ranging in solutions dealing with carrying the bicycles completely outside of the train to packing them into certain areas devoted to bicycle storage onboard. Table 2 below describes more prominent ideas that were expressed and compares the frequency of written ideas with the modeled ideas.

	exterior bicycle carrier		convertible/multi-space		interior storage	
	written	modeled	written	modeled	written	modeled
Participant 1		1	1			
Participant 2	1	1	1	1	1	1
Participant 3			1	1		
Participant 4	1	1	1	1	1	1
Participant 5			1		1	1
Total	**2**	**3**	**5**	**3**	**3**	**3**

Table 2, Prominent ideas expressed by participants

The lower left image in figure 2 (participant 3) offers the idea of convertible/muti-use space and seating within the train interior that allows for bicycle, luggage, wheelchairs, baby strollers, or personal seating space. All of the written responses expressed the idea of convertible or multi-use space and seating, usually coupled with a need for "peace of mind" that the bicycle was secured and/or in close proximity to the cyclist. These responses also indicated that this feeling of proximity and security could apply to luggage, strollers, and other large cargo items. For example, one participant said, "When bicycles are not being stored, benches can fold in place allowing for additional seating. It would also make an excellent place to secure wheelchairs." Another said:

> "While on the train, the biker would want peace of mind in knowing that his bike is secure, safe from damage, and may also want a way to see it/know where it is. A person without a bike does not want to wait for the person with the bike…Seats could fold up to accommodate passengers and bikes…"

These statements and participant model files inspired the eventual concept model and sketches depicted in figures 3 and 4. Although the convertible/multi-use seating idea was modeled specifically by only one participant and indicated in 3D space by two others, all participants appeared to think that this was a good idea and wrote about it. Other ideas could have been explored but convertible multi-space seating offered the greatest participant interest.
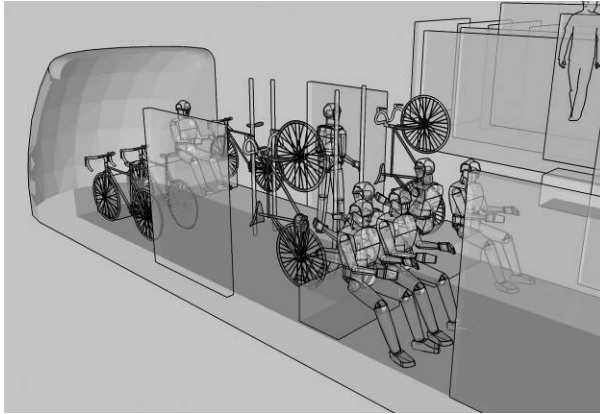
Fig. 3. Concept SketchUp model file created by the author

Figure 4 depicts research based ideation sketches that further refine concepts that were inspired by the participant files. The model file depicted in figure 3 and these sketches center on the convertible multi-space seating suggested in the participant files and allows the cyclist to remain in close contact with the bicycle. Bicycle positions at the end of the train allow for those who cannot lift their bicycle. Other positions throughout the car convert to seating and are positioned near doorways.

At this point the author injected his own insights and interpreted/explored form development. Combined with the ideas and directions of the participants, the concept SketchUp model, and ideation sketches depicted in figure 3 and 4 are an example of the essence of Co-Design. As suggested in table 2, there are other possible solutions. However the concept depicted in figure 3 and 4 are assumed to hold promise in balancing bicycle storage and maximum seating capacity in a conventional light rail interior – an assumption that could be disregarded if other stakeholders (e.g. light rail system officials or engineers) entered the design process and indicated that, for example, bicycles could be transported on the exterior.
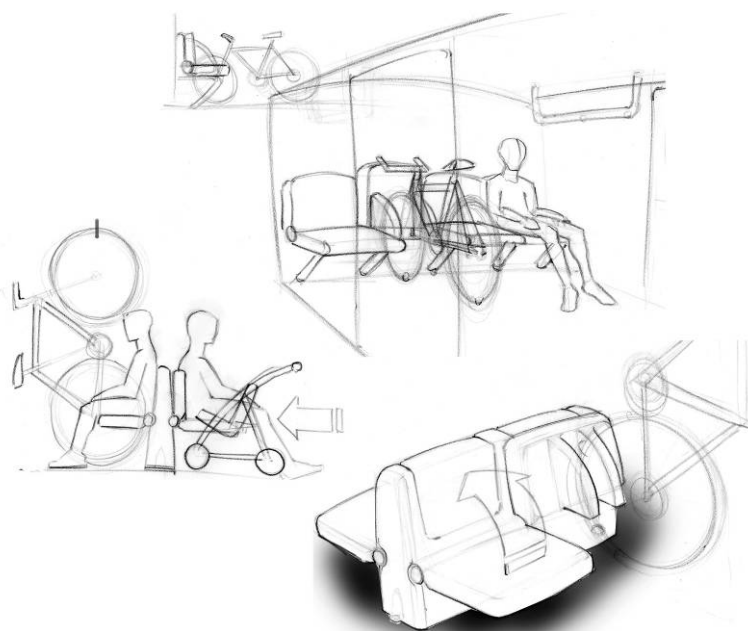

Fig. 4. Concept ideation sketches created by the author

Within one day after the participants completed their work a follow-up interview was conducted. This semi-structured interview helped evaluate CoDeViS as a help or hindrance during the exercise. A summary of participant responses follow:

Question # 1 - Did the 3D modeling aspect help you express what you were trying to describe?

- Having a layout and scale definitely helped orient and express ideas
- It was slightly frustrating to move things around and could have used more instruction on how to use SketchUp. Had to fight with learning SketchUp
- Had a difficult time creating certain forms that were not there
- Had to simplify what they wanted to make
- The participants used approximately one hour of their time to learn the basic functions required to complete the 3D work, then another hour to design

Question #2 - If you didn't have the 3D modeling part and only the paragraph to write, how would it have been?

- The modeling aspect helped orient ideas in realistic space
- Working with the SketchUp model and the actual 3D constraints of scale, dimension, and space helped create and refine concepts
- If they were more proficient at SketchUp it would have been a "breeze"

Question #3 – So, a bit of difficulty with the tool but otherwise it seemed like a good way to get information from people. Do I have that right?

- "Definitely… it adds that 3D perspective on things, arraigning things, I mean it makes sense to do that…"
- "Yeah, and the variety of shapes that were available already was really helpful because I can't imagine trying to do it without them…like what would we have done if there weren't any bikes there…"
- "It almost seems like Google Sketch-up is almost as good as having…big foam blocks and you could actually arrange them around and you being the person…its like the next best thing…it does help…"

Conclusions

The theoretical basis for CoDeViS is well justified and is one of several appropriate approaches that can address design problems where Co-Design is used. However, a simpler modeling program and interface should be developed to overcome the slight irritation participants feel initially when given Google SketchUp to work with. If participant expectations were somehow reduced or given more time or instruction with the tool, and because of its relatively simple interface, SketchUp could be successfully employed on similar projects. It can be acquired free of charge after all.

Answers to the follow-up questions above appear to confirm the potential value of CoDeViS and further development of a convertible multi-space/seating concept for light rail. However, to a degree, SketchUp was difficult to work. The 3D aspect of the exercise was "definitely" an aid in creating and expressing ideas, but perhaps the difficulty of modeling a complex form, like a convertible seat, required too much effort. An interesting aspect of the 3D modeling experience was that it appeared to enhance the spatial awareness and context of the participant; while not giving quite enough ability to easily model what the participants were thinking. The participants tended to compensate by relying on words rather than the 3D aspect. Perhaps the 3D environment and objects also helped create more "real-world" designs, or encouraged participants to create concepts within limiting factors. Understanding the criteria, parameters, and real-world limitations that exist is critical to any design activity at some point in the design process. Answers to question #3 appear to support this argument.

Part of the potential value of CoDeVis is simply the power to generate many ideas that are inherently connected with the end-user. Most practicing industrial designers understand the value of generating many ideas early in the design process. Having a broad array of ideas to choose from enhances creativity and helps open the gateway to innovation.

Additionally, CoDeViS is research based ideation; meaning that participants help create the designs and they are intimately connected with the ideas that are expressed. Refined concepts and/or prototypes can be traced back to the desires of the participant. With this traceability comes confidence and justification to pursue a particular design direction. Confidence and justification are critical to business decision making (e.g. a company president wants confidence and justification before money is spent on production).

Interestingly, if this study were conducted on a large scale, quantitative based ideation sketches could be produced representing a certain percentage of participants and their preferences. Greater numbers of ideas would be shared and patterns could be better assessed – increasing confidence and justifying design direction. CoDeViS enable most stakeholders, with computer access, the ability to take part in the design process in a meaningful way at low logistical costs and at a rapid pace. However, CoDeViS has some apparent strengths and weaknesses. Table 3 compares aspects of CoDeViS with Physical Velcro Modeling.

Aspect of Co-Design	Physical Velcro Modeling	Co-Design in Virtual Space
Participant Kit Creation	Anyone can make	Must possess moderate 3D computer modeling and possibly website skills
Kit Cost	Depends on level of detail and volume, high	If kit is created on existing hardware/software, low
Kit Distribution	Travel time and/or postal fee	Instantaneous, free if using email or existing web site tools
Facilities	May need additional space or can be expensive	Participant access to a computer anywhere

Travel Time and Cost	May be significant	Not significant
Participant Scheduling	Timing and coordination is rigid, can be difficult	Within a time frame, flexible for participant
Analysis	Usual data input and transcription time	Reduced data input and transcription time
Participant Training	Low	Moderate
Interaction Level	High	Low
Amount of Participants	Limited	Unlimited

Table 3, Aspects of Physical Velcro Modeling and Co-Design in Virtual Space

Using CoDeViS would drastically reduce the face to face interaction of designer and participant, there would be some basic computer technology requirements, and training issues should be considered. However, compared with physical Velcro modeling, CoDeViS could be employed if cost, time, and other logistical concerns are significant. Product development costs and time are almost always limited and design research is a notion/activity that is continually debated in many companies because of these limitations (Arnold, 2006, September 18-20).

The case study in this paper highlights some of the relevant challenges and potential opportunities that CoDeViS offers. Specifically, participants appreciate the virtual 3D aspect of the method. It allows them to participate in the comfort of their own home, at their own pace. Only basic familiarity with common computer programs is required of the participant. However, the case study indicates that the participants expect using SketchUp to be simple and straightforward. Instead, learning SketchUp introduces a new problem for the participants to deal with. The 3D aspect of the method could be improved through simplification and/or better training. The CoDeViS method could be more appropriately applied with participants who are of the "millennial generation" (i.e. generation Y, or born between1980 to 1997) where common modes of personal interactions occur on-line and computer navigation is second nature. Although using SketchUp proved to be a challenge, the participant could be reminded that high levels of detail are not necessarily needed while modeling. After all, the main purpose of Velcro modeling or CoDeViS is to give the participant tools to express ideas and be creative without refining all of the details of their design – encouraging the participant to create an experience rather than just a product or thing. The designer, who has the skills of refinement, would appropriately build upon the ideas.

The potential for curriculum enhancement in design education and research opportunities exist in the area of 3D CAD collaborative technologies that enable design team members and stakeholders to co-design with each other remotely (e.g. using the internet for collaboration with those in other countries) (Arnold 2006, September 6-8; Shyamsundar & Gadh 2001), and with potential end-users through participatory design methods found in human-

centered/co-design approaches (Sanders & Williams 2001). CoDeViS is one approach that merits investigation, development, and practical application. The need for research in this area should be of growing importance – considering the global nature of product development today.

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