Playing with Digital Media: Enlivening Computer Graphics Teaching

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Are there better ways of getting a student to learn? Getting students to play at learning can encourage comprehension by engaging their attention. Rather than having students' fascination with video games and entertainment limited to competing against learning, we can direct this interest towards learning computer graphics. We hypothesize that topics having a recreational component increase the learning curve for digital media instruction. To test this, we have offered design media projects with a playful element as a counterpart to more step-by-step descriptive exercises.

Four kinds of problems, increasing in difficulty, are discussed in the context of computer aided architectural design education: 1) geometry play, 2) kit of parts, 3) dreams from childhood and 4) transformations. The problems engage the students in different ways: through playing with form, by capturing their imagination and by encouraging interaction. Each type of problem exercises specific design skills while providing practice with geometric modeling and rendering. The problems are sequenced from most constrained to most free, providing achievable milestones with focused objectives.

Compared to descriptive assignments and more serious architectural problems, these design-oriented exercises invite experimentation by lowering risk, and neutralize stylistic questions by taking design out of the traditional architectural context. Used in conjunction with the modeling of case studies, they engage a wide range of students by addressing different kinds of issues. From examining the results of the student work, we conclude that play as a theme encourages greater degree of participation and comprehension.

Keywords: computer aided design pedagogy, architectural education, games and play
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I. Introduction

Psychologists confirm that a playful attitude gives a person the chance to experiment by reducing associated penalties (Lieberman, 1977). Playing is a restorative activity that involves spontaneity and humor to make an enjoyable experience. Early in life, play provides a chance for children to practice future skills and develop logical thought by trial and error. Within a safe, restricted realm, a player gets feedback from each experimental iteration, accumulating knowledge of the system. While play is generally an open-ended activity with unique and ephemeral results, games have a predictable outcome because they involve well-defined systems. Games capture attention because they provide an unfolding understanding of the rules of a system.

For design education, playful, generative problems can provide a counterpart to more controlled descriptive problems at all stages of development. Formal games provide understanding of design operations particularly when a particular designer's logic is embedded in the rules. Later, looser, more imaginative exercises can engage students in using emotion-filled narratives less dependent on logic.

Constrained geometry play encourages experimentation and fosters an understanding of basic elements and transformation operations. By adjusting parameters of limited operations, students are exposed to formal possibilities of design variation. The elements for initial exercises are simply design primitives. For more complex exercises, beginners can use elements made by others in kit of parts construction. As the students develop, they can generate custom elements, developing their own rules for these kits. Once their descriptive skills are competent, they can engage in creating their own imaginative environments and transforming their own designs. These problems provide a preparation for virtual studio collaborations that will then test communication skills.[1]

This paper will focus on play as a motivator, explaining advantages and difficulties in the use of these design media exercises. The exercises were developed by the author and A. Scott Howe at the University of

Oregon, from problems used at the University of Hong Kong by Cheng and the University of Michigan by Howe. The most recent versions of the classes have been an introductory computer graphics course (160 undergraduates and 40 graduate students); the sequel for undergraduates, a hybrid physical and digital design communication course (116 students); and two intensive modeling courses for upper level students (12 students each). These classes have used Autodessys FormZ and Adobe Photoshop software on both Windows and Macintosh platforms. Previous classes have used Autodesk AutoCad, Engineered Systems Powercadd and Artifice Design Workshop.

II. Background

The exercises stem from a tradition built on shape grammar and kit of parts approaches. The concept of formal grammars provided the opportunity to articulate the elements and operations for generating architecture through programming (Mitchell 1990, Knight 1994). Radford (1997) and Schumacher (1997) have explained the value of using games in CAD education: playing means interactively learning the rules or design rationale of a system. For them, building-block games have provided a simple stepwise introduction to the complexity of computer modeling.

Kit of parts exercises take the idea that through limited standard parts, students can focus on specific design concepts. The digital version provides a constrained CAD toolkit which can be enlarged over a sequence of increasingly complex elementary architectural design exercises. (Zhang Lie 1996, Ataman 1996). Working with different sets of building blocks allows the students to understand the design ramifications of their initial decisions (Roe 1995). More recently, the ETH's Phase X project structured a large number of student transformations of peer compositions using Internet programming (Schmitt 1997, p.7-8, Kolarevic 1998a).

The kit of parts projects simplify tool usage and the mechanics of making. They encourage experimentation within a limited framework, and when done well, increase the chance of creating a beautiful solution. The problems are limited by existing in an isolated formal environment devoid of context, so the potential for over-constraining the design possibilities into a numbing regularity must be avoided. However, for beginners, the benefits of a more controlled learning environment outweigh the costs by ensuring exposure to a wider range of issues and providing more design freedom after they have developed fluency in the media.

Transformation exercises come from the same spatial manipulation tradition of shape grammars. They can reinforce the concept of an invariant building type with alternative expressions and show how forms can be rearranged to have different meanings. Because creativity can be defined as recombining the familiar into the new (Lieberman 1977), exercises requiring re-arrangements simulate creative capabilities. Designers need flexibility (the ability to adapt to new circumstances) and spontaneity (the ability to generate new circumstances). In the area of digital design, Sanchez-de-Valle (1996) asked students to study Transformer toys prior to designing folding temporary structural assemblies. Through the toys, she demonstrated how forms have meaning dependent on configuration and context while giving a spirit of playfulness to the class. Through the use of folding structures, she showed how computer modeling tools are well-suited for spatial manipulation.

As their predecessors do, our formal manipulation problems (geometry play, kit of parts and transformations) develop a sense of design composition while providing practice in digital modeling. We complement these formal problems by explicitly engaging the imagination in problems using childhood dreams and in transformation problems that start from artwork. Creating dream-like environments have been more typically used for younger students, but projects like the Alice-3D animation project show that college students similarly enjoy creating their own imaginary environments (Pausch 1998). Edward Allen has spoken eloquently about how childhood dreams can be a "wellspring of architectural delight".[2] He sees the innocent imaginary worlds as a place for periodic revitalization, a fresh counterpoint to an otherwise familiar, banal environment.

In the context of computer aided architectural design teaching, Glenn Goldman has been successful in using cinema as a stimulus for the imagination. His students first digitally recreated movie sets and then generated animations of their own fantasy versions. The project illustrated how beginning generative problems with descriptions of precedents can also be a strong learning paradigm.

III. Playful problems

We will describe how we have used ideas from these examples to create problems that inject playfulness into the digital design curriculum. The goal has been to use the spontaneity, humor and joy of play to increase student motivation and performance. A description of each problem type will be followed by its advantages and disadvantages encountered. We have documented these experiences to guide others in using the exercises with optimum results. While the problems have been customized for a particular course context, the problem types can be adapted to other teaching environments. The simple design problems can be assigned either as abbreviated exercises in the context of "design media classes" or as more extensive problems in an introductory design studio.

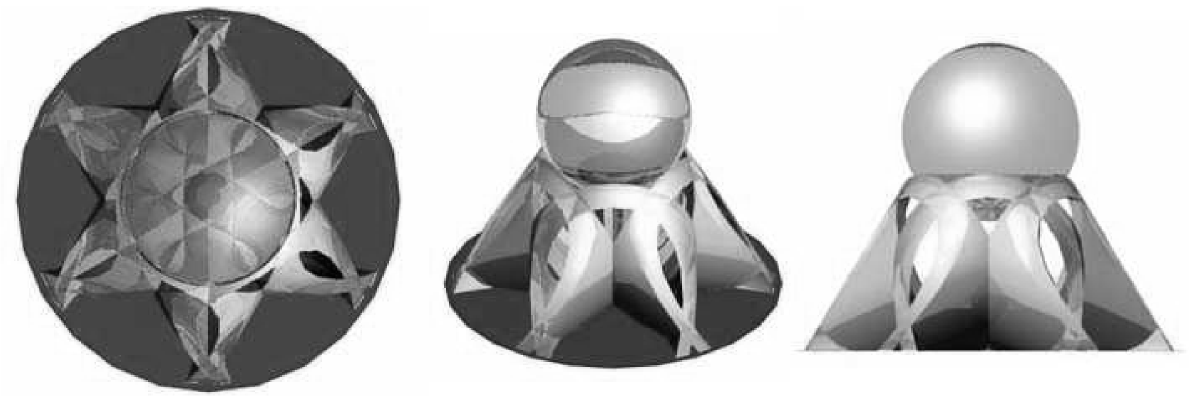

Fig. 1. Circular array of Boolean results by Padru Kang

IIIA. Geometric Compositions

In the most elementary stages, problems based on geometry are geared towards producing a delight in abstract beauty. While they are learning the software interface, students are given strict directions on how to perform exercises so that they use the desired tools and they have a very high chance of success. The problems encourage students to use simple geometric transformation such as translation, reflection, and rotation to create pleasing compositions, first in 2D and next in 3D. For example, a first exercise based on a graphic design book (Wilde, 1991) asks students to express concepts such as terror, balance, movement, etc., by composing five white squares on a given black background.

Students are encouraged to try out multiple variations of one motif so they can compare different design strategies and understand the limits of the problem constraints. While students can learn in depth about complex geometric transformations by replicating beautiful examples, they get more practice in creating their own work through generative problems. Forms such as Chinese lattice patterns, Japanese joinery and Islamic tile patterns provide excellent examples for emulation and are well suited for developing fine control of graphic operations.[3]

One geometric play problem illustrates the use of Boolean operations for discovering emergent form. Students are given an explicit set of instructions for first generating a form through Boolean intersection and then creating a circular array of the result. The instructions are accompanied by an illustration of possible results. Students are encouraged to substitute different primitives and experiment with the amount of intersection and the proportions of the primitives. The effect is like handing them a 3D Spirograph-like drawing toy. The circular array makes it possible for even the most awkward Boolean result to generate a set of objects with beautiful symmetry and unity.

Advantages:

- All students can do the problems.
- Most can create visually pleasing results.
- Students could quickly generate forms following the cookbook-style directions.
- On seeing the example image, several students jumped into teaching themselves rendering with minimal instruction.

Disadvantages:

- The problems are not completely foolproof: (i.e. not all the Boolean intersections exploit the operation successfully)
- Students have difficulty matching the rendering quality of the given example without explicit coaching

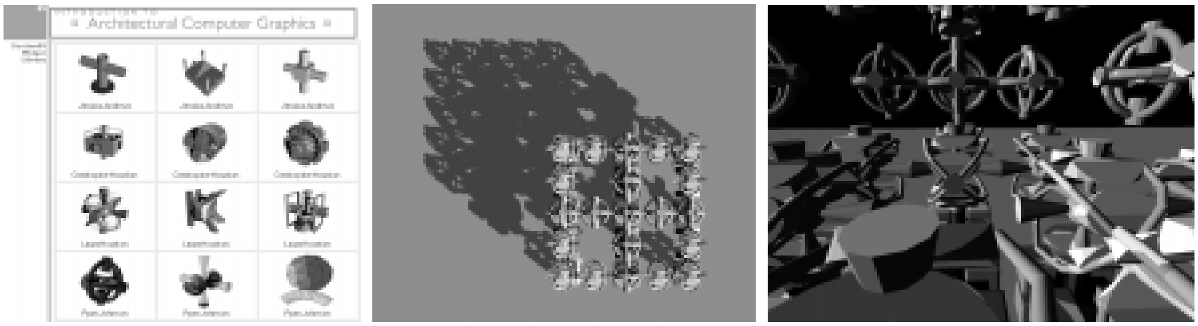

Fig. 2. Web-based catalog of playground parts (left) , Assemblage by Christopher Houston (right)

IIIB. Kit of Parts Assemblage and Exchange

Problems which constrain both design components and operations are naturally followed by those constraining the components but freeing the operations. A kit of parts strategy boosts the modeling ability of the students by giving them detailed parts while controlling the results. Building up structural parts provides an opportunity to learn about digital organizing tools such as hierarchical grouping (Cheng 1995).

To utilize the large size of the introductory modeling class (200 enrolled), we encouraged students to share their ideas as much as possible[4]. For all assignments, students could easily browse the posted assignments of their classmates from the class web page. For our kit of parts assignment in the introductory computer graphics class, we assigned 40 graduate students to build from components designed by their classmates. This exercise was inspired by the Phase X project done at the ETH and utilized design collaboration projects. In the first week, each student used Boolean operations to create three building blocks for playgrounds. They posted the 3D data files and corresponding image files of these blocks to their personal web account using a standard naming convention. On the class page, the files were consolidated into a Web-based catalog. Students could then download components of their choice and build up abstract play structures.

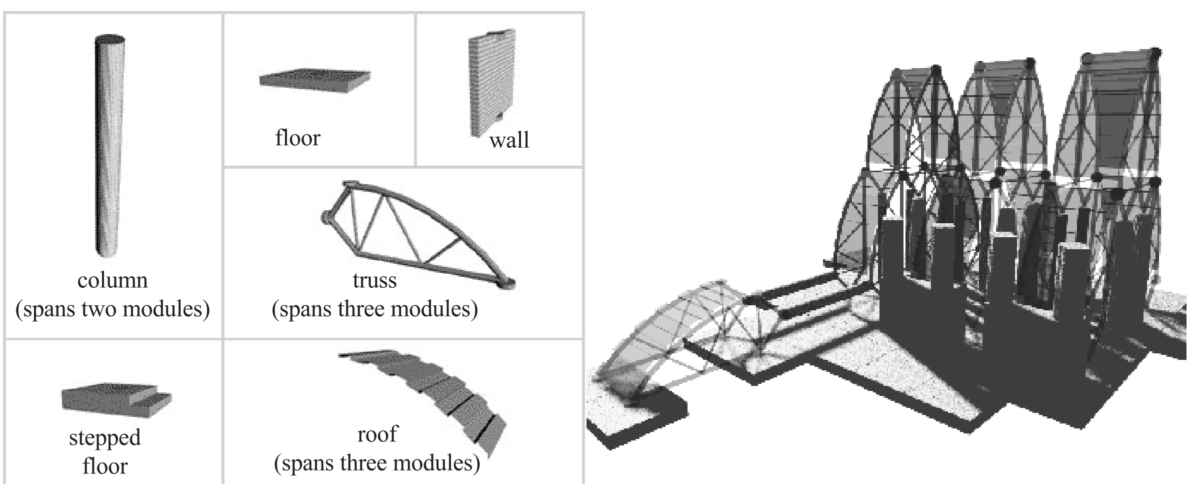

Fig. 3. Instructor-provided High-tech building components (left), Assemblage by Jon Zegers (right)

Since we did not know whether the Web-based exchange would go smoothly, a control group of the 160 undergraduates in the class used components supplied by the instructors. Students could choose from Classic, Gothic or High-tech sets of building components all of which were designed to connect at face centers of a cubic module.

Advantages:

- The digital kit of parts works well in many teaching contexts because components are easy to model and assembling components exercises basic geometric operations. They are particularly instructive when time allows students to model components based on a specific architectural monument. Reassembling the components into new variants requires an understanding of the initial designer's logic. (Hersey 1992, Mitchell op.cit., Knight op.cit.)

- Even beginners can create 2D window and door symbols by copying a given elevation and use the symbols to create new hypothetical elevations.
- The web-based catalog of students' components motivated all students to upload on time as missing submission files appeared as broken links by the student's name. The complete catalog provided a large play chest of widgets to choose from.

Disadvantages:

- The instructor-provided components worked better than the student-generated components because they were designed as a complete system with simple linear, planar, curved and connecting elements.
- While beginning design students can be given modular components, advanced students need the freedom to design their own components and create their own structural hierarchies. Defining element roles (column, truss, mass wall, etc), modular grid dimensions and connection types (T, L, X, etc.) can help students develop a robust set of parts that can be shared. In design problems of longer duration, long-span projects provide an opportunity to test out the range of a kits' functionality.
- Finding the right degree of constraint for kit of parts problems may require optimization. For example, when we asked the students to create plan variations from classic plans cut into jigsaw puzzles, we originally asked that they re-use every single element exactly one time. The results were awkward because students needed to use elements in different quantities.

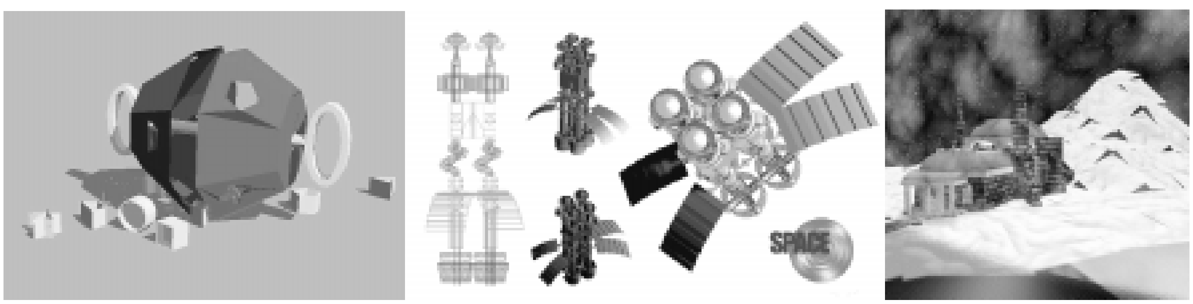

Fig. 4. Toy modeled by Dan Bisell (left), Spaceship by Eugene Chung (center), Castle by Daniel Berens (right)

IIIC. Dreams from Childhood: imaginary environments and childhood nostalgia

As the modeling skills of the students improve, they are increasingly able to describe environments of complexity. In order to encourage more expressive results, we have tried out a number of different subjects for intermediate students. We have received positive student reception for projects whose focus draws students back to childhood fantasies. This is consistent with the use of guided visualization or fantasy exercises used in writing or art classes. Teachers have found that providing an open-ended narrative invites students to embellish ideas and bring out their deeper emotions (Hall 1988, p. 159-179).

Our colleague Glenda Utsey describes this approach as "play to learn, learn to play". She has found that first year students produced excellent results using Design Workshop to model their childhood toys and Photoshop to collage the resulting renderings. The students regarded their subjects with such affection that they lavished much more time and care than on the typical assignments.

Combining the kit of parts concept with the nostalgia for childhood, in Fall'97 I asked our students to design modular playground equipment and demonstrate how the pieces could be combined. As an early modeling exercise, students were able to use very simple modeling and transformation exercises to create joyful compositions.

At both University of Michigan and University of Oregon, Scott Howe has had similar success with castles and spaceships. In one scenario, students were to design a virtual playground that could be used in a fantasy medieval video game. The students were to use their architectural design skills to create spaces wherein the game could occur. In another scenario, students were assigned to design a spaceship that would be used in a science fiction movie. The assignment had two parts: design of the overall spaceship, and detailed design and modeling of a part of the spaceship that conceivably would be used to build a physical set for the movie. In both scenarios the loosely defined typologies allowed students to draw on a wealth of imagery without holding back their imagination. Thinking of video games gave them inspiration for dramatic scenarios and aided them in understanding wayfinding issues. Designing a movie set or a video game let them dream of future careers in the way that A.C. Gilbert's Erector® sets helped previous generations dream of building bridges and dirigibles.

Advantages:

- Students become very engaged with the projects.
- Students can build up their worlds with increasing levels of sophistication, allowing each student to control the level of difficulty.
- Students show more experimentation when the projects are imaginary rather than serious in nature.

Disadvantages:

- Imaginary environments can be poorly proportioned and unattractive if the students have little training in architectural history or exposure to visual design. Without a design example, it is possible for students to get away with sloppy modeling, poor use of color, etc.
- As these looser problems require more coaching for success, students could benefit from getting feedback from more sophisticated peers.
- An alternative to increased feedback is combining open-ended problems with meticulous architectural modeling (case studies) so that students get exposure to spatial organization in context.

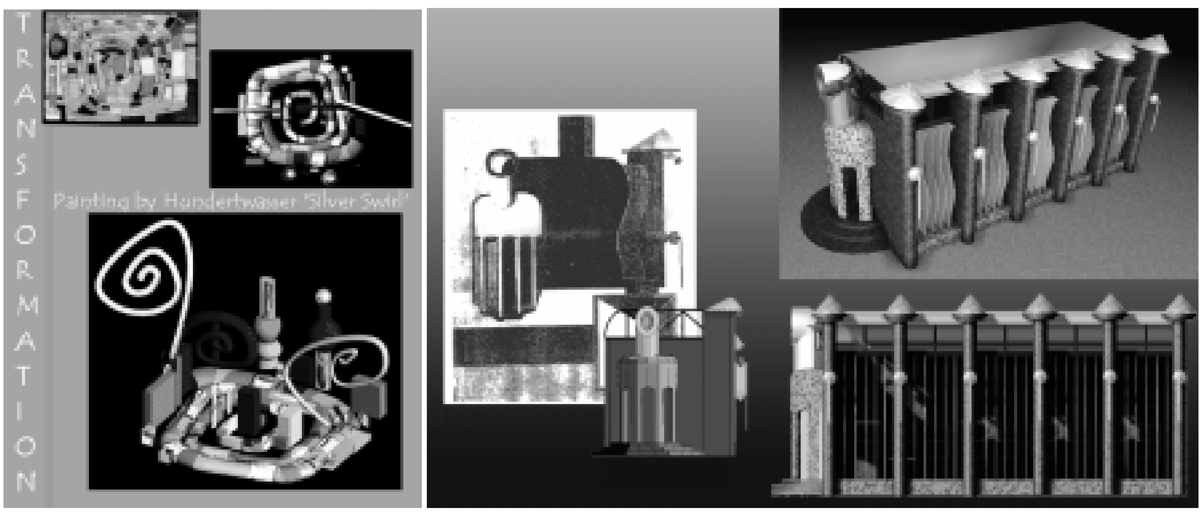

Fig. 5. 2D to 3D transformation of Hunderwasser painting by Kara Larsen (left), Corbusier painting by Dan van Calcar

IIID. Transformation

We place larger emphasis on design transformation exercises because seeing multiple possibilities in a design concept is critical for developing refinement strategies. Through these problems, students grasp how powerfully computers facilitate geometric transformations. Two types of problems focused on spatial transformation: 2D to 3D drawing to building and 3D to 3D sculpture to building (Inhabitation Transformation).

The first problem, from Drawing to Building, built on a project from a Spatial Composition class taught by James Tice. From a problem originally given at Cooper Union by John Hejduk, James Tice provided graduate students with 2D drawing fragments from which they were to generate 3D architectural compositions, optionally to include a narrative. The students approached the project by first making a 3D computer model and then by constructing a white cardboard model. Students projected the lines of the drawing into space, creating digital perspective views to support the narrative.

Advantages:

- The most successful examples took advantage of the computer rendering to explore lighting and material properties, especially color and texture, which could not be depicted in the cardboard models.
- Students gained insight into differences between media by doing the same exercise in digital and cardboard models.

Disadvantages:

- Observing the results from two years, we have found that the cardboard models had more spatial richness than the computer models. We could not tell whether this was due to the media used or to the digital to analog sequencing; class agendas forced the digital study to precede the analog one.

A second project, Inhabitation Transformation, offered to undergraduates in 1997, asked them to model an abstract geometric sculpture from given examples as their first 3D homework. They were next asked to visualize the sculpture in another context and transform it into a building or an environment by changing factors such as scale, orientation, materials and context. Finally, they were asked to elaborate on the model, by drawing it in plan and section and rendering it scenographically with light and color. Re-reading the forms stretched their imaginations. Enlarging or reducing the forms helped attune students to architectural scaling elements.

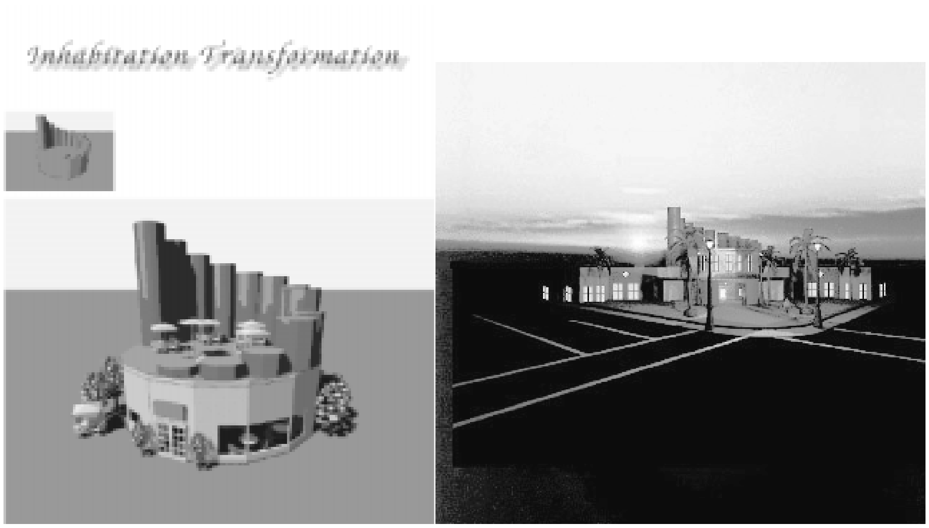

Fig. 6. Sculpture transformation by Nick Chen (left) and David McHugh (right)

Advantages:

- The project exposed the student to modern sculpture and challenged their imaginative powers.
- Students could choose the level of difficulty of their projects. Those choosing simple sculptures had a lot of freedom in their development.
- Some students saw their graduate student counterparts developing playgrounds and used that as a basis for creating free compositions.

Disadvantages:

- Working on their own personal designs required less study of architectural principles and standard documentation than working on an existing design.
- Some students were stuck for several weeks with a strange project because of their random choice of a sculpture. (In reaction to these difficulties, the next iteration of the course reverted to descriptions of architectural monuments phased by similar technical skills. These descriptive problems were preceded by a series of short generative problems.)

Problem Type	***Playful Aspect***	***Learning Domains***		
		Cultural Enrichment	***Design Process***	***Technical skills***
Geometric compositions	*Building blocks engage imagination,* *Basic design encourages play*	*Promotes understanding of model examples taken from cultural contexts*	*2D and 3D composition, aesthetic judgement used with parametric variation*	*Working with geometric primitives & transformations*
Kit of Parts	*Promotes engineering vision, sharing of building blocks*	*Use of elements must follow design logic*	*3D composition in an architectural context*	*Using symbols, Using the Web for teamwork*
Imaginary Environments	*Builds on childhood dreams*	*Involves mythical building types*	*Represent mental image via computer graphics*	*Controlling modeling & rendering*
Transformations	*Challenges mental spontaneity*	*Aesthetic choices embedded in the artwork*	*Requires engagement with scale*	*Using drawing projections, model refinement*

Table 1. Problem types engage students while addressing learning domains

Elements of the four problem types described above (geometric composition, kit of parts, childhood dreams and transformations) can be combined to create hybrids. For example, for an intermediate design studio, the program of a local YMCA gave the opportunity to engage the theme of recreation while addressing long-span structural issues with a kit-of-parts approach. Students who have encountered the approaches in a design-oriented digital methods course are well prepared to address a more sustained design problem along the same themes.

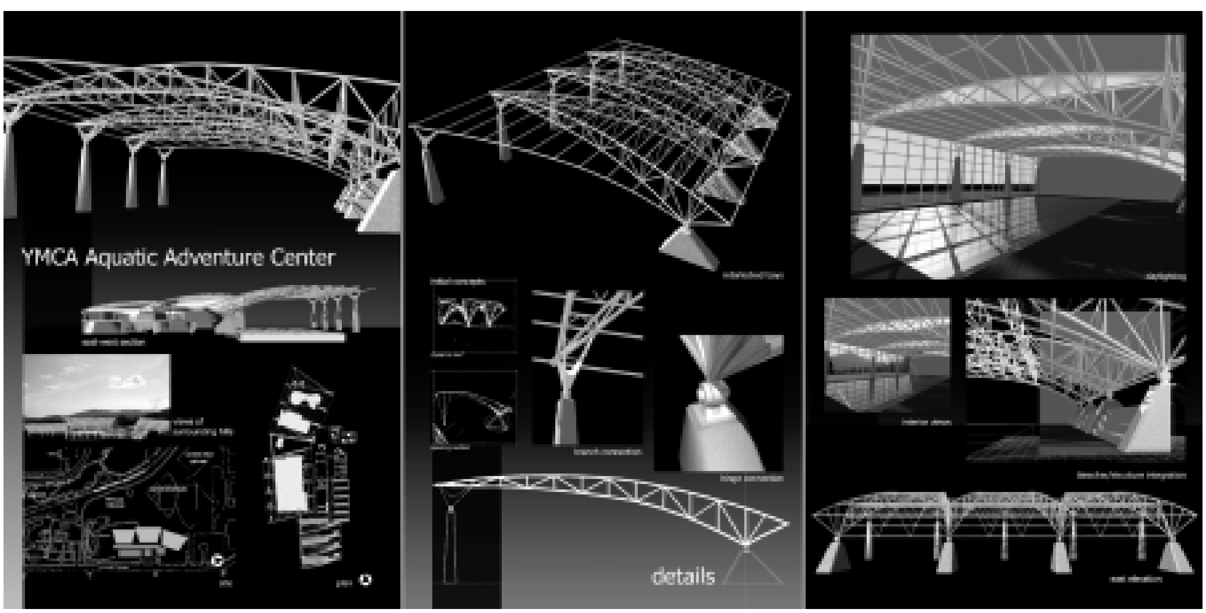

Fig. 7. Design by Petra Wilm shows kit of parts construction used for a recreation building.

IV. Discussion

Learning benefits

Why are these basic design problems and fantasy environments useful? We found that taking the problem out of the typically serious architectural realm lowers performance anxiety. Students have a natural tendency to want every project in their major to show their genius even when their design skills are rudimentary. Reducing down to abstract design elements or injecting a more light-hearted fantasy subject gives students a chance to play around with form-making and composition. Students hone compositional skills outside of the building environment first and then study architectural monuments more carefully by interpreting architectural or urban scenarios with the acquired digital skills later.

Taking a problem out of standard architectural settings forces students out of default modes of thought. Questions of building style and the naive imagery of a novice designer are less problematic when projects lie in the fantasy realm. Students cannot easily fall back on their preconceptions and personal biases. Instead of relying on architectural cliches, they are invited to use their own creativity. They must approach the problems with their eyes wide open, using their own visual judgment in developing solutions. Even in cases where there are built historical examples, as in the case of castles, the wide variety of imagery from children's literature and entertainment gives students poetic license to unleash their imaginations.

Assessment

Because our teaching context has been continuously changing, the supposition that playful problems promote learning comes from the visual evidence. Factors such as the software, hardware, instructors and classroom settings have been adjusted, making a systematic evaluation difficult. Inspecting the student work, we can see that the students are improving their ability to use modeling, rendering and image-processing software. From this approach, they are learning to use digital tools within the context of design rather than in a purely descriptive way.

Measuring student engagement, creative ability and digital skills would provide a fuller assessment of the proposal that playful problems improve student learning. First, problem types would have to be defined: creative composition, game learning, descriptive representation. Second, equivalent problems with the same learning objectives would be created. Third, achievement of the students would have to be checked. Engagement could be measured by reviewing videotapes of students working, for example. Another indicator of engagement could come from student retention numbers and course evaluations. Assessing the creativity of design solutions is more difficult, at a gross level; creativity could be roughly measured by counting the number of atypical solutions a student can generate for a problem (Lieberman, 1977, p. 88). Competency in applying the software can be tested by giving a timed problem in a controlled lab environment. Testing students for comprehension of computer concepts would further reveal results of each problem type. The large variability of student abilities would require a large sampling.

Curriculum building

The attributes, advantages and disadvantages of creative problems must be considered in building up a balanced curriculum. For example, compared to descriptive problems, generative problems tend to have less cultural information. In describing an existing work of art, a student is confronted with the subject matter, but in creating new work, a cultural context needs to be provided. If open-ended problems are presented with visual examples, students have strong models for their creative play.

The 3D to 3D sculpture to building exercise, Inhabitation Transformation, provides an example of how cultural enrichment can be added by interweaving descriptive and creative work. The student works at describing a model, then generates a transformed version. The chart below summarizes how the different phases of the problem address different learning domains. Each phase focuses on developing specific technical skills; together they introduce aspects of the design process in a cultural context.

Phase	*Playful Aspect*	*Learning Domains*		
		Cultural Enrichment	***Design Process***	***Technical skills***
1. Draw the sculpture (Descriptive)	---	*Learn about art through description*	*Mimic the sculptor's compositional strategy*	*Arrange 3D primitive forms*
2. Transform into architecture (Generative)	*Draw on the imagination*	*Study building scaling elements*	*Creatively re-read & enhance a physical form*	*Refine a 3D Model*
3. Draw plan & section cuts: (Descriptive)	---	*Follow examples of plan and section drawing*	*Find new perceptions through new representations*	*Use orthogonal drawing conventions*
4. Render 2 views which match 2 photos (Descriptive)	*Play photographer*	*Examine architectural photography & analyze it*	*Use viewpoint, color and lighting for emotional response*	*Control light, viewpoint & color*
5. Collage rendering with site (Generative)	*Imagine a context for the form*	*Choose suitable background & foreground elements*	*Shape meaning through context*	*Use image processing for juxtaposition; match view & light*
6. Put images into a portfolio or web page (Generative)	*Play curator or graphic artist*	*Study models for graphic design*	*Unify a presentation*	*Use desktop publishing or web authoring to communicate ideas*

Table 2: Addressing different learning domains: 1997 Inhabitation Transformation weekly phases

Examining how problems take advantage of playfulness and address cultural, design and technical domains is a good start towards building a comprehensive, balanced digital curriculum. By further analyzing whether assignments are architectural or non-architectural, individual or social in nature, additional learning styles can be addressed and learning strategies taught.

Future directions

Objectives for future digital design teaching include testing how to extend the playful problems and improving the context in which they are introduced (more tutorial help, more buzzgroup interaction in the lecture setting, etc.) Because digital design required linear thinking for technical aspects and lateral thinking for creative aspects, different aspects of childhood play can be developed. The systematic learning needed for the complexity of computer graphics applications could be taught through a series of step-by step assignments like a game. The motivation of earning points could help students in getting through the all aspects of a program. We could use the reward structure of a game where multiple attempts are encouraged and progress is rewarded by attainment of the next achievement level.

Keeping track of achievements by tutorial group "teams" could further the social dimension of play in large classes, especially when tutorial meetings are reinforced by Internet interaction. As beginners come in with greater skills, we can require more Web-based group-work supported by structures such as bulletin boards, chat rooms, video-conferencing and electronic office hours. Team members become a test audience for students improving their communication skills.

Lateral thinking strategies, which are at the heart of open-ended play, could be embedded into graphic exercises to stimulate the creative side of digital design. To encourage fluency in design scheming, problems could require quick generation of multiple preliminary solutions followed by development of a chosen variant.

To reinforce the idea that interpreting ambiguity can invigorate design, students could be asked to draw or model an ambiguous figure or form more than one way. Students would show how a composition of forms could be created by more than one configuration of primitives and how different the transformation of those configurations could be. This would stimulate awareness of how the CAD modeling decisions can constrain design possibilities.

To generate new perceptions in problem-solving, a lateral thinking strategy uses serendipity, as in looking for an inventive connection between random words and the problem at hand (Adams, 1986, p. 109). Applying this idea to the design realm, Dan Herbert (1997) has proposed that CAD systems could incorporate a wild card transformation to wake up designers to new possibilities. Teachers could inject an element of surprise by requiring students to invert their compositions, work with the Boolean negatives or incorporate an element from another person's work. The effect would be analogous to looking at a painting in progress turned upside-down: new views bring new understanding.

V. Conclusion

This paper describes experiences in using problems with a playful approach. The strategy is to bring out childhood imagination, use motivations from childhood play and increase enjoyment of learning. The projects suggest to students that they can return to a child's frame of mind. They remind students of a time when everything was new and learning was done by experimentation without pre-emptive judgements. They encourage students to use the free expression of childhood.

Since design students need to exercise the creativity that is so plentiful in children, we need to find ways to incorporate more playful attitudes throughout the design curriculum. Injecting the freedom of childhood play could increase student comfort while also increasing creative achievement.

We invite others to document the strengths and limitations of teaching techniques and learning exercises so that a clear menu of possibilities would be open for discussion and refinement. This is particularly important in the digital design area, where sharing strategies for teaching that incorporate creativity will allow us to take fullest advantage of technical advances.

NOTES

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1. More advanced students engage in virtual studio projects which have a similarity to the war simulation techniques used in the 60's. From these, Henry Sanoff and others developed design games as a method for bringing together different points of view. For example, Henry Sanoff's games have stimulated public participation in designing community facilities such as schools. (*Journal of Architectural Education*, Gaming - Special Issue, Sept 1979; Sanoff's *Design Games*, Los Altos, Ca. : W. Kaufmann, 1979). In the educational realm, these provide the opportunity for participants to learn project-oriented skills such as problem solving and resource gathering while being exposed to a simplified version of "real world" situations. The games provided feedback for sound decisions, rewarding the acquisition of particular knowledge or skills (Tansey, 1969, Reese, 1977, Cameron, 1977).

2. Allen, Edward. Unpublished lecture, University of Oregon, Fall 1998.

3. Prof. Jerzy Wojtowicz has used these and Japanese joinery in his modeling classes at University of British Columbia.

4. For the four classes, students were given a very simple template of linked Web pages. After uploading the template set to their own accounts, they simply uploaded images of their weekly assignments using an image naming convention.

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