Teaching CAD with Language Learning Methods

From: J. P. Jordan, B. Mehnert and A. Harfmann (eds.), Representation and Design, Proceedings of the Association for Computer Aided Design in Architecture (ACADIA), Cincinnati, Ohio, 1997.

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ABSTRACT

By looking at computer aided design as design communication we can use pedagogical methods from the well-developed discipline of language learning. Language learning breaks down a complex field into attainable steps, showing how learning strategies and attitudes can enhance mastery. Balancing the linguistic emphases of organizational analysis, communicative intent and contextual application can address different learning styles. Guiding students in learning approaches from language study will equip them to deal with constantly changing technology.

From overall curriculum planning to specific exercises, language study provides a model for building a learner-centered education. Educating students about the learning process, such as the variety of metacognitive, cognitive and social/affective strategies can improve learning. At an introductory level, providing a conceptual framework and enhancing resource-finding, brainstorming and coping abilities can lead to threshold competence. Using kit-of-parts problems helps students to focus on technique and content in successive steps, with mimetic and generative work appealing to different learning styles.

Practicing learning strategies on realistic projects hones the ability to connect concepts to actual situations, drawing on resource-usage, task management, and problem management skills. Including collaborative aspects in these projects provides the motivation of a real audience and while linking academic study to practical concerns. Examples from architectural education illustrate how the approach can be implemented.

I. INTRODUCTION

Many design schools are still struggling towards seamless integration of digital media into the curriculum despite the proliferation of technology. One of the reasons that traditional media has been so slowly replaced is that the teaching of valued design and visual literacy skills have been inextricably intertwined with the teaching of media skills such as drawing. The successful track record of training the eye and the hand together can hardly be challenged if computer media skills are taught in isolation. Instead, we can see digital design learning as a complex process requiring understanding of architectural order, visual judgment and technical methods. In this way, the graphic communication of computer aided design is similar to the verbal communication of foreign languages: both are tied to content and context. By mentally representing the computer learning process with the model of language learning we can transfer well-developed pedagogical methods to a new field.

This paper will start by discussing how CAD teaching and language teaching are similar, then it will examine successful language learning techniques and show how these techniques can be applied to learning CAD. The study springs from the need for a larger framework in which to see technical skill training and from a desire to build on a well-developed pedagogical approach. Its inspiration stems my personal experiences as a student of enthusiastic, methodical, and ever patient teachers of Cantonese and Mandarin. The study necessarily carries the bias of my own experiences as an architect and educator surveying another field for material applicable in my own teaching. Many of the ideas were first introduced in Cheng 1996.

Of course there is not a perfect fit between the disciplines: Language learning has relatively stable verbal and written modes of receiving and expressing: listening, speaking, reading, & writing, while computer representation has various modes which quickly evolve with technology. The verbal aptitude which facilitates language learning may not overlap with the visual aptitudes needed for computer graphics. Despite these differences, this study will examine how concepts from the well-established field may be applied to an emerging discipline. The goals of this study are to foster greater understanding of how technology can be integrated into

teaching, to provide practical ways to implement curriculum improvement and to point out possibilities for further study.

(For clarity, "CAD" and "digital design" will be used interchangeably to mean exploring and expressing design ideas with computer technology. My examples primarily refer to visualizing tools such as graphics, modeling, rendering, animation, multimedia, virtual reality rather than to analysis tools.)

II. SIMILARITIES BETWEEN LANGUAGE STUDY AND CAD STUDY

Simply stated, graphics and words are both vehicles for communication. Mastering these vehicles is the challenge in learning to use CAD visualization tools or a foreign language. Both require framing ideas in new ways in order to communicate. A person may know what he wants to say, but he may not know how to express it. This pragmatic goal of expression provides a natural motivation, but provides little insight in achieving the goal. Thus, CAD learning just as language learning requires guided practice towards mastery, with the goal of clarity and ease of expression in a variety of situations.

The architect's role as negotiator between clients, contractors, builders and colleagues makes expressive skills critically important. Whether in the planning, design or construction phase, architects play a pivotal role in conveying and interpreting information. As architects must increasingly rely on computers to help organize, process and publish information for others, the ability to communicate ideas through digital media becomes an essential part of architectural education.

Beyond the basic need for communication, we can examine how linguists approach their field. Language study has three emphases which may be transferred to computer aided design: study of structure, communication and context. (Finegan, 1992) Structural linguists seek to clearly describe the organization of language, both universal characteristics and specific differences of different languages. In contrast, foreign language teachers often focus on the goal of communication, stressing the function of language use as a means of social interaction, with structure as a background enabler. Sociolinguistics look at how the situation of the speaker affects language use, looking at contextual gender, class and regional characteristics affect the application of language. As these emphases parallel different learning styles, addressing them in computer aided design teaching can improve teaching effectiveness.

Levels of structure: elements, phrases, sentences, essays

Communicating ideas subtly is accommodated through complex, evolving systems in both digital design and language. Computer programs for architectural design attempt to mirror the kinds of elements and operations that are used in architectural design. As such, they incorporate geometric primitives which may be grouped into motifs, and then coordinated into major assemblies. This parallels how words may be grouped into phrases and then more complex structures. The student's task in either case is to understand how to use elements to build syntactically correct and semantically accurate constructions.

In architecture, the need for an ordering system arises from sheer complexity. The large number of specialized building elements requires that a building be represented in every case with some level of abstraction. Even a thick wall line on a floor plan stands for a complex construction such as wood studs and gypsum board or bricks and mortar. Whereas traditional media allows flexibility in encoding and interpreting graphic marks, CAD systems require that the designers consciously parse the building. Organizing the building data into a series of hierarchical systems (HVAC, structural, circulation) allows maximum use of the information.

Using these parts "appropriately and generatively" (Gardner 1991: 65) requires a combination of content and technique: knowledge of the underlying architectural order and facility in precise expression.

At the most basic level, primitive geometric elements (points, lines, arcs, cylinders, etc.) are like key words which must be deeply understood. From linguistics, we can see that it takes more than just acquaintance with a single facet. According to Faerch, to fully "know" a word one must:

1) know its full meaning potential, not just one specific meaning.

2) know the appropriate situations for using the word
3) know in what ways the word can combine with others
4) know the relations between the word and other words

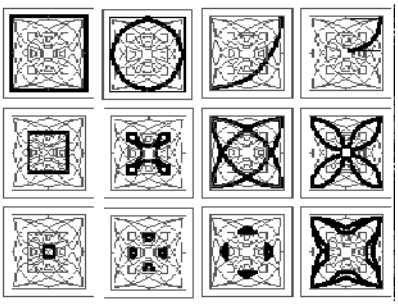


Figure 1 - Geometric components highlighted in a Frank Lloyd Wright tile design

Frank Lloyd Wright's geometric designs show how deep knowledge of very simple elements can provide the basis for elegant compositions. His work reveals how to combine elements so that they remain true to their natures but add up to a greater whole. For example, an arc which calls out its own center may also be used in radial four-fold symmetry to emphasize another center. Articulating similar designs with digital media requires a conscious definition of the geometric elements by key points such as an arc's center and radius. Awareness of these key points allows a student to combine into different kinds of symmetry patterns, which can correspond to phrases with correct syntax.

Expression depends on "not only the literal mastery of syntax, but also the capacity to construct narratives of different degrees of complexity" (Gardner 1991:74). If syntax is taken to mean the rules which govern the structure of a system, then CAD students have to master many different kinds of syntax. Syntactic rules govern the way that the computer can accept information, as in command word order, as well as higher level ordering of data structures and architectural system components. Stiny and Mitchell's (1978) study of Palladian villas showed how one architects' decision-making process could be decomposed into elements and operations, allowing it to be mimicked with computer graphics. This study spawned similar shape grammar studies which articulated other architects' design processes into linguistic rules, showing the robustness of the analogy between architecture and language. These related studies also used computer graphics programming to reflect design operations. (Koning and Eisenberg 1981, March & Stiny 1985)

In teaching, setting out a structural framework of design elements and rules provides a scaffolding for learning the media for representing them. But what enlivens learning is getting towards the goal communicating by exercising newly learned skills in a meaningful way.

Communication focus for more effective learning

Focusing on clear communication can humanize a potentially cold and intimidating computer-based curriculum and can create a better learning environment. Without neglecting to show how the computers' use in manipulating logical, geometric order, we can also show its utility in connecting human beings. (For notes on the importance of human perception and non-linear thinking in the computer-aided design process, see Laseau 1994.) If students can use computers to help convey ideas to others, they start to understand how computers can facilitate the less rational side of architecture. Encouraging the class to be a networked community can mitigate the anonymity of a large class size. And using wider networks for collaborations can create compelling connections which increase motivation and open vistas.

Interaction is commonly used in language class because the incentive of a social relationship can stimulate response and along with it, creativity in the method of responding. The person interacting must adapt to his partner's comprehension and tailor a response to a particular situation. Whether in written or graphic form, expressing ideas for an audience requires re-articulating ideas and reconsidering principles and priorities. Particularly if a student must translate from one medium to another and abstract the subject, he or she must reexamine the matter. (Cheng 1995) “The teacher’s task is to give students the opportunity to rephrase, restructure and reorganize the content and form of dialogues and readings.” (Kramsch 1992:69) Therefore

projects which require the students to represent existing building designs are not merely copying by exercising cognitive and technical skills in a new media.

Teaching according to audience context

Focusing on communication skills works particularly well in a situation where verbal proficiency is uneven. For example at the University of Hong Kong, the ubiquity of English, Cantonese and Mandarin means that it is difficult to master clear expression in even one language. Exercises in Web authoring, desktop publishing and live interactions address this deficiency by cultivating graphic, verbal and written expression. In U.S. schools where student backgrounds can be much more diverse, Web projects can be similarly effective as students may choose the project's focus & level of difficulty.

Addressing and novices and seasoned professionals require different treatments. Following the analogy of CAD to language, teaching CAD to novices can be like teaching a child to talk, while teaching CAD to traditionally trained designers is like teaching a foreign language. In the latter case, one can rely on familiarity with graphic expression of architectural order. Because inputting computer graphics requires abstraction of graphic or architectural components into their underlying structures, creating images which are technically correct requires familiarity with drawing conventions and construction methods.

In teaching of experienced designers, we can look to foreign language learning, where previous knowledge about the native language guides the learning of another language. "Background knowledge serves as scaffolding to aid in encoding information from the text." (Stall 1995) Familiarity of what makes up a language gives a strong basis for learning one: the student knows to some degree what they are searching for and what are the possibilities of the end result. While traditionally computer skills were introduced after basic design and drawing classes, the trend is now to integrate the study of design and all kinds of visual media.

For novices, teaching traditional media and digital media together within the context of an intense architectural design program could be analogous to a bilingual or multilingual immersion. As digital media becomes enmeshed into our culture at every level, the separation of digital media teaching into an isolated specialty makes little sense: many students now entering university feel as comfortable with a mouse as with a pencil. The challenge is to provide a rich environment for the learning of the design content with sophisticated media skills, both traditional and digital, so that designers don't lose touch with architecture's basis in materiality. Designers need see the different strengths of different media. "The architectural practice and education of tomorrow is ... not in one medium/approach but in many media/approaches." (Bermudez 1997: 58)

III. CURRICULUM FRAMEWORK: STEPWISE DEVELOPMENT TO MEDIA FLUENCY

The parallel between computer media and language allows us to utilize step by step linguistic teaching methods in teaching the complexities of CAD. We can structure a curriculum focused on digital expression with the concepts and methods for gaining natural fluency found in language teaching. Language teaching defines the goal of communicative competence as having four linked parts (Faersch 1984: 168):

1. Linguistic competence, or understanding about sounds, words and grammar
2. Pragmatic competence, or the ability to use language correctly for specific situations
3. Strategic competence, or the ability to solve communication shortcomings with strategies
4. Fluency, or the ability to express with ease.

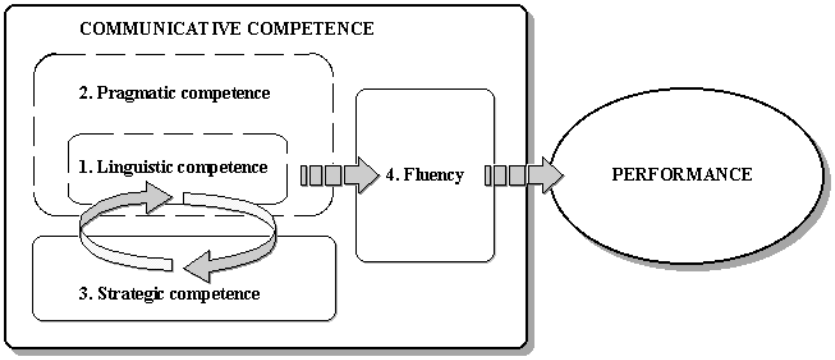


Figure 2 - Components of communicative competence - from Faerch 1984

In the CAD curriculum we aim for the same goals, but in the realm of the visual expression through digital tools. We can achieve these goals by following the stepwise model of language learning, reflecting the need to build up skills gradually. Beginning classes provide an introduction to digital concepts through a sampling of different applications. In intermediate classes, students are given structured ways to use methods in their design projects. Once they have passed through these levels, students can freely use the methods for design and research. In optional upper level courses, computer techniques are supported much in the same way that language is developed in writing-intensive classes. These classes use computers as vehicles for investigating and expressing ideas.

Evaluation of proficiency is important for advancing from one level to the next. While quantitative testing is most easily done at the least meaningful level of command syntax, practical testing analogous to an oral exam can be an effective gate. Building on the success of using time-limited design problems by Julinski (1995), I initiated a practical test. At HKU, I required students to model and render a simple object of their design such as a chair, window or plant and then present it in a simple HTML home page, all within a timed 4 hour session. This was a great incentive for the students to become more self-sufficient in using the software. Because the large class had to take the practical test in batches, student discussion and pre-cooked components can make evaluation difficult. Therefore, in a more recent version at UO, I allowed access to resource material and consultation with tutors to create a more positive situation and to encourage resourcefulness.

For individual courses, the time-tabling of classes can be modeled on language methods. For foreign language learning, frequent short practice sessions are more effective for retention than infrequent long sessions. Limited resources make daily contact or requirements impractical, limiting teaching to perhaps two or three times a week with the help of student teaching assistants. Within a coordinated program, it is possible to reinforce computer media lessons with requirements from other classes such as design studio.

Looking with more granularity at the level of class exercises, CAD teaching can still get ideas from language teaching. In beginning foreign language classes, the students start by mimicking the teacher's correct pronunciation of words, then phrases and sentences. Rather than repeating words, design students practice using geometric primitives such as lines, arcs and planes, quoting motifs or spatial arrangements which are analogous to phrases. Students can follow CAD tutorials which lead them through models of correct usage of the commands just as language students parrot model sentences. By initially substituting parts into given examples, they can successfully create their own fledgling variations. Once students can step away from the tutorials and use the software functions for their own drawings without following specific direction, they have gained useful knowledge.

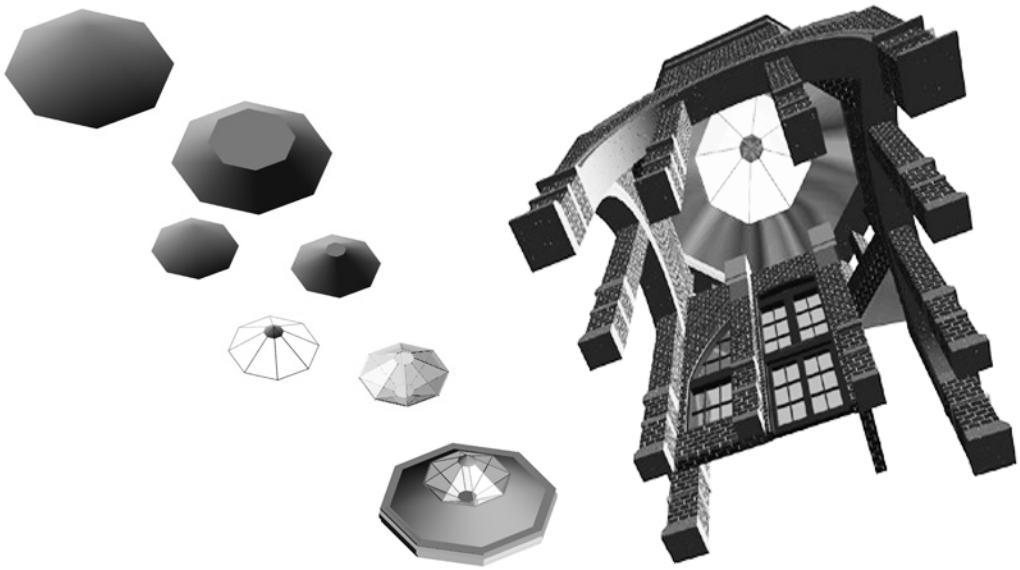


Figure 3 - Geometric syntax: Stepwise refinement of the entry pavilion to Moore, Ruble Yudell's Willamette Hall combines simple geometric elements into a complex form. Created in FormZ by University of Oregon (UO) student Edwin Lee.

BEGINNERS: Applying basic CAD principles in design

In linguistics, one of the basic goals is to clarify universal structures and describe differences. (Finegan 1992) A similar approach can be taken in showing the underlying structure of computer information by emphasizing common qualities about data manipulation across a series of applications in the context of their particularities. In order to work knowledgeably, students must understand

1. the nature of digital organization and manipulation
2. the importance of the fit between form and content

Introducing concepts such as *data types, modifiers, attribute styles* in simple applications can provide the abstract backbone that accelerates learning of more complicated ones. Emphasizing the underlying concepts promotes deeper meaning and enhances recall.

The appropriate applications will change as architectural design software evolves. While 2D drafting and 3D modeling and rendering are the classic CAD workhorses, image-processing, network communications, animation, spreadsheets, databases and multimedia presentation tools all have utility for architects and could be available in an architectural curriculum. Teaching several applications in one course allows teaching about data translation and file dependencies (such as Object Linking and Embedding).

In order to use these computer concepts, students must understanding the how they can relate to the subject matter, architectural design. They must see that the organization of an architectural computer model should closely match its subject. In doing so, students must employ architectural understanding in building up digital structures with organizing tools such as symbols, layers and hierarchies. Teaching about these structures is best illustrated with examples of precedents which emphasize the organizational parallels of architectural language and data organization.

From these examples, students can be guided into using the operations and data structures for their own design work. Within the limited time frame of professional education, it is efficient to develop beginning design and computer skills together through simple composition problems. Presenting beginning design students with a stripped set of elements is a classic strategy for emphasizing the nature of the elements and basic principles to be used with them. For example, beginning painters may be constrained to a limited palette of Red Yellow and Blue so that students must derive their own color mixtures and see how the primary colors can generate a broad spectrum. A restricted set of design elements and operations matches both a focused educational agenda and an elementary technical level.

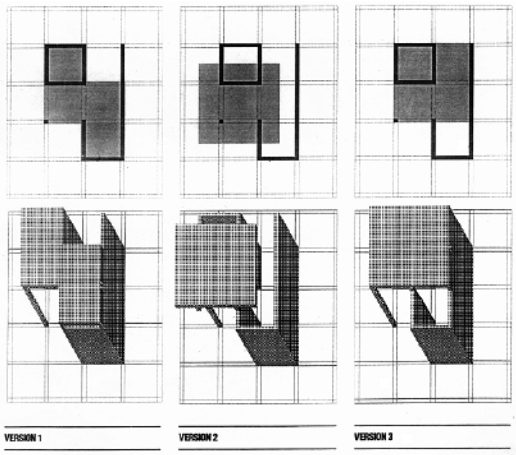


Figure 4 - Roof variations as a basic digital design exercise, "Roof should be on 3 m grid in support of the defined space: not identical but in dialogue."-- Zhang Lie .

An example of using vector-based CAD objects as a primer for design has been used by Zhang Lei in Nanjing (1996). In a series of CAD-based composition exercises, he starts with the most restricted set of a vertical wall

and column and then gradually adds a roof plane, landscape orientation and the possibility of roof construction variations.

INTERMEDIATE: Toolkits and guided media use in the design studio

A transition occurs when students can explore the medium for their own purposes. The concept from language study called "threshold competence" (Jones 1995) names a hypothetical minimum proficiency level at which a student can start to use the language for his or her own communication needs, reinforcing formal study. For example when a student has a skeletal reading knowledge, they can begin to read magazines for fun.

Being able to rely on tediously learned skills for free exploration gives a great feeling of progress, which can otherwise easily fade in long, challenging courses. The counterpart in CAD study is when a student who is initially forced to grapple with machines becomes motivated to try out the new technology for him or herself. In this case, mastering one piece of software makes learning then next one much simpler, especially with interface consistency.

To get the best of both digital and traditional media, the students initially can use guidance to help them make sense of the range of choices. The students can compare the possibilities inherent in each media as they gain confidence.

As the students become more facile with CAD, they can be provided with more sophisticated toolkits for composing with correct architectural syntax. As a "kit of parts" problem emphasizes the hierarchical nature of building assemblies, it can easily be adapted to show that CAD structures should mimic the structural hierarchy. Students can construct their own hierarchical assemblies, or they can be given more sophisticated parts and rules created as a learning assignment by older students. At the University of Hong Kong (HKU), we took the first approach for second year undergraduates, starting with an case study of structural precedents done in groups, so they could examine how different systems work with an architectural space. The students then went on to design their own structural elements which could built up into first bays and then a site-specific building. To complement the computer models, physical models were specifically used to find a site massing, where serendipity of form would be most useful and for intuitive exploration of gross structural behavior of the bay design. (For more about using kit-of-parts to emphasize the parallel between data structure and building structure, see Cheng 1995.)

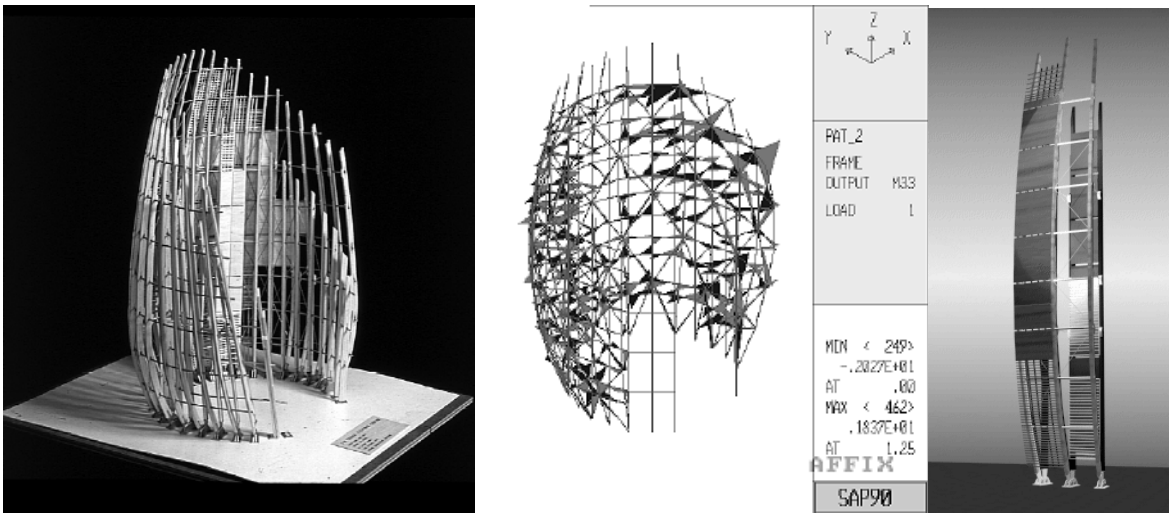


Figure 5 - Precedent study of Renzo Piano's Jean-Marie Tjibaou Cultural Center with physical model, SAP-M structural analysis and Autocad/3D Studio digital study of construction module. Team project by HKU second year undergraduates Patrick Luk, Genevieve Daphne Wong , Choy Suk Ling, Li Laam Hung, & Leung Lo Ming.

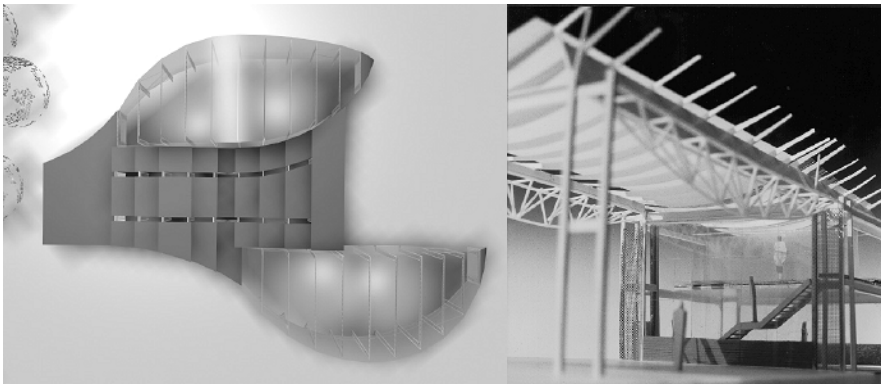


Figure 6 - Studio designs following precedent studies: Autocad model rendered in 3D Studio facilitates parametric variation & material variation, physical bay model provides intuitive structural stability. Thomas WONG Ming Hong (l), Dicky LIU Wing Cheong (r).

Toolkits not only give the beginning students an opportunity to work with a limited construction vocabulary but can also provide advanced students a chance to encapsulate the knowledge of architectural rules in the form of a usable shape grammars. The advanced students study either a building typology or a specific architect's way of working, attempting to extract the basic building blocks and the rules for combining them. The pieces are digitally modeled in 3D and then rules for assembly are either explicitly stated or for the more sophisticated, the rules are embedded into a user interface.

Two robust examples of this approach also come from Asia: in Taiwan, Mao-lin Chiu (1996) led older students in creating the rules and elements for row-house plans. Younger students used the parts to create their own plans and then developed them three-dimensionally. At the Chinese University of Hong Kong, where Li and Tsou (1996) lead students in building historically correct variations of Chinese temples on the Macintosh using complex "Dougong" bracket elements. The construction of a usable toolkit and the design its interface are research challenges for the older students.

ADVANCED: Free Media-Intensive Projects

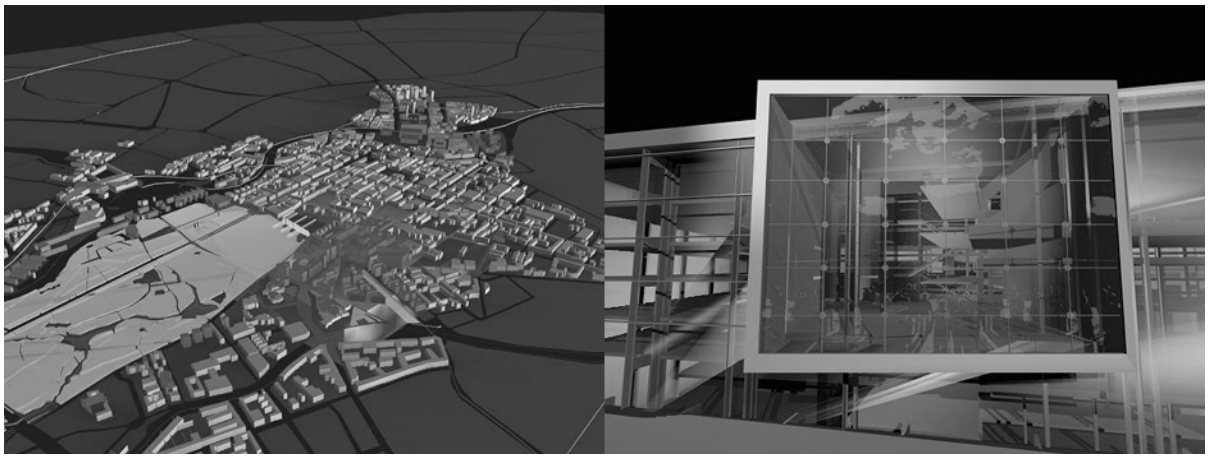


Figure 7 - Independent thesis project connecting architectural design to urban scale via CAD visualizations (Falk Kagelmacher, HKU supervised by Thomas Kvan)

Promoting resource-using skills through projects

Once students have the practical knowledge and skills to teach themselves, teachers need not explicitly define which media to use when, but should give feedback on the use of media in projects, following the model of

writing-intensive content courses. Projects provide scenarios for applying techniques appropriately and often create situations which require strategic thinking.

An important aspect of a project-based curriculum is that it requires active thinking and response to constraints, rather than the passive absorption of attending lectures. Understanding of the thinking process, aka metacognitive skills, assist in the performance of tasks and give them long-term value. Students must take charge of managing the project because in planning, organizing, executing and reviewing a project, a student's "task awareness", a metacognitive skill, is increased. Newell & Simon (1972) explain that a person must visualize

1) the task goal and subgoals
2) the possible states of the task in progress
3) the constraints of task performance.

By working on projects, students exercise these planning skills and become better students. In addition to defining the scope and focus of the project they need to identify appropriate media tools and apply them effectively.

For upper-level students, both design and research projects can be the vehicles for becoming fluent in the use of computer media. In elective subject courses students can exercise digital research and publishing techniques individually or in groups:

1) Accessing databases and library resources through networks
2) Organizing, analyzing, processing and archiving information
3) Integrating different forms of information into multimedia
4) Visualizing information for presentation and publication

Example: Communication in collaboration projects

> "Teaching language as social interaction calls for a diversification of classroom formats, such as group and pair work, to maximize opportunities for interactions of various kinds. It also calls for the increased use of 'authentic' materials, whose social meaning lies beyond the illustration of grammatical rules."-- Kramsch 1992:70

One way to bring the design communication process to life and exercise media skills in a practical situation is by giving students an audience. If the audience is remote, the distance makes digital information a strong and inexpensive method of communication. The students are pushed into a realistic experiential learning situation: if they don't communicate, then their partners tell them that they are disappointed. The live audience provides a motivation for getting ideas across clearly as working relationships develop. Because the students themselves also act as an audience for their partners, they are reminded of what makes the communication obfuscated.

In an example of an annual Virtual Design Studio project, the students' contrasting cultural backgrounds has provided a strong motivation for communicating about common design projects. For the spring of '96, representatives from Univ. of Hong Kong, Univ. of Toronto, Univ. of British Columbia, Cornell University, Taiwan Chiao Tung University and Warsaw Institute of Technology worked together on a project encouraging **collaborative partnerships through complementary roles**. Each project team had at least one Hong Kong student to act as the local designer or consultant and one foreign student to work together on a monument to Hong Kong's 1997 handover to China. The foreign students were initially given little information about the territory so that they would need to get it from the Hong Kong students. Communication was primarily through e-mail, secure FTP accounts, Web pages, and video-conferencing (CU_SeeMe & AT&T Picture Tel).

PROJECT FILES:

All files displayed in chronological order (based on posting date).

Thumbnail:	Filename:	Time & date posted:	Size(Kb):	Author:
	Sketch1(sk1.jpg)	Fri,Mar 8 1996, 3:00 PM	66.311	Tim
	Sketch2(sk2.jpg)	Fri,Mar 8 1996, 3:00 PM	47.732	Tim & Marie Matchbook idea
	Proposed Site (site.jpg)	Sat,Mar 9 1996, 4:00 PM	57.082	Tim & Marie Site discussion
	Proposed monument (monument.wrl)	Mon,Mar 11 1996, 5:00 PM	84.021	Ricky & Tim

Figure 8 - Virtual Design Studio '96: HTML table logs the design stages of a jointly designed Monument to Hong Kong's 1997 handover to China

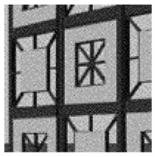
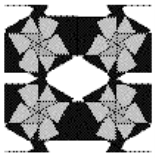
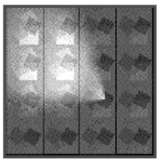
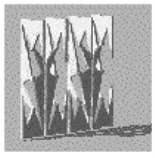
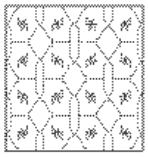
Original		Transformed	Comments
	**deconstructed & reconstructed -->**		Lloyd Cunningham first examined the components of Marcus Koch's screen and gently worked within their conventions. Finding that too rigid, he freely recombined the pieces into a sculpture.
	**re-materialized -->**		While Greg Thomson created a screen which implied layering of rotated & shifted geometric elements, Richard Furbacher took the shapes as stencils for a subtly painted continuous panels.
	**combined -->**		The laser cut pieces stimulated new combinations.
	**dramatized + floated -->**		Playing with the lasercut components of Greg's screen led to some more fantastic visions. JJ Lee created towers complete with guy wires and scripted their destruction.

Figure 9 - Real & Virtual Space '96: Using lasercut wood pieces, image files & DXF files, UO & UBC students created playful folding screen compositions. (http://darkwing.uoregon.edu/~design)

Figure 10 - Virtual Design Studio '97: Communicating a Sense of Place: UO student Midhat Delic's rendering of Antonio Sant'Elia's La Citta Nova was combined with UBC's Sonya Carel's collage in Photoshop to create a link portal. New image (right) shows the customized Hypernews interface embedding an image's URL into a form-input message.

Other projects in the series have focused on Chinese housing design, physical vs. digital modeling, and the sense of Place on the Internet. Technical descriptions, programatic scenarios and critical analysis of Virtual Design Studio projects can be found in Cheng (1994), Wojtowicz (1994) & Wojtowicz (1996). Despite technical, financial and time constraints which have limited the quantity and quality of synchronous design discussions, live communication has given a compelling vitality to the network exercise. Sharing of pragmmatic problem-solving has been very effective since live text, video and audio of varying qualities can link sites as technical aspects are optimized.

Cultivating a strong design dialog requires attention to human factors that make communication work well. The networked studio gives us an inviting way to explore the potentials of digital design with colleagues many miles away.

IV. LEARNING FROM LANGUAGE LEARNING: METACOGNITIVE SKILLS

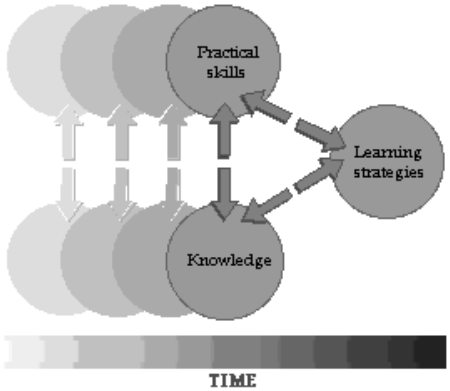


Figure 11 - Relevant knowledge and practical skills change , whereas relevant learning strategies remain constant.

The parallels between language and CAD learning allow us to take advantage of learner-centered teaching methods which have been tested in language classes. Most important is the idea that we need to teach learning strategies and attitudes (Gardner 1991:71) rather than just pragmatic skills or knowledge. Although the commercial allure for students to become wizards at the latest release of AutoCad is strong, more lasting is the ability to figure out emerging tools. The ephemeral nature of technology means that we have an obligation to build learning skills into our CAD classes. Language classes provide some useful principles.

Start by supporting learner autonomy

Giving the students the skills to learn on their own is important not only because of the reality of large class sizes, but also because each person eventually needs to find his or her own way. Luckily, computer tools often are accompanied by self-paced tutorials, on-line help and reference manuals. But language self-access centers have shown that merely providing these materials is insufficient: we must provide self-access skills along with self-access tools. The flood of information on the WWW makes it especially important to build resource-finding skills and resource-using skills for efficiently targeting, finding and using information. Making sure students know how to get into applications, find the self-help tools, and then save or quit is very basic, yet extremely important.

Language teachers have found that drilling very beginning students with stock query phrases meaning "I couldn't hear you" and "I couldn't understand" allows them to learn more effectively through interaction. Students in computer classes need to be aggressive about finding out

"What does the tool or command do?"
"What actions are required?"
"What's the correct syntax?"
"Show a simple example of this function."
"Guide me in using the tool step-by-step"

Those who are too shy to ask questions in class must be able to ask these questions from their computer's on-line resources.

Developing a Learning Culture

"Every teacher of a second language is a teacher of a second culture as well" (Saville-Troka 1976). Teachers convey much more than the content of the material, which is why classroom lessons are needed to supplement books. Students benefit from an orientation towards the context of computing because language teaching shows that students focused on integrating into a language culture perform better in their learning than those with narrower instrumental goals such as meeting a requirement. Design teachers can promote a computer "culture" in several ways. By creating a work environment conducive to cooperation, there can be a classroom culture. To supplement the limited face-to-face contact, World Wide Web sites, electronic mail listservs and news groups can disseminate attitudes and ideas which are supportive of the learning agenda.

Another sort of computer "culture" comes from putting computers in their professional design context. Readings and examples of how technology affects the creative and pragmatic possibilities in different specializations will alert students of the importance of digital know-how. Guest speakers from practice or software development can widen perspectives on the application of classroom techniques.

Cultivating healthy learning attitudes

The importance of the student attitudes towards learning is clearly shown in language education and sometimes neglected in architectural schools. Ideas such as "enabling goals" and "threshold competence" recognize that feelings of achievement spur further exploration. (O'Malley 1990) Working with the students to guide them in achievement of these intermediate steps can build the self-confidence which supports independent exploration. Attainable "enabling goals", such as short graphic exercises, give a chance for the students to become familiar with the mechanics of putting pieces together in a correct fashion.
Studying different ways to learn, or *learning strategies*, can also stimulate positive attitudes by providing more control over the personal educational process.

Imparting learning strategies

Language literature categorizes strategies as *metacognitive* (process-oriented), *cognitive* (direct), and *social/personal* (people-oriented). While the categorization comes from language learning, the strategies are valuable for life-long learning in any field.

Strategy Category	Definition	Example
metacognitive	arranging the learning process	planning, directing attention, monitoring, identifying problems, evaluating compensating
cognitive	direct ways to learn	recognizing, repeating, creating mental links, analyzing, structuring, elaborating, summarizing, translating
social/personal	using interaction and self-regulation	questioning, cooperating, encouraging, lowering anxiety w/ music, checking on emotions

Table 1 - Learning strategy categories
(condensed from two schemes by Oxford and O'Malley & Chamot as presented in Tudor 1996:203-206)

In the context of language study, students who 1) seek frequent practice chances and 2) use patterns and rules for intelligent guessing are cited as successful learning strategists by Rubin (1995). Training how to use strategies is most effective when it is highly explicit and when the learner made aware of them within the context of projects. (Oxford and Ehrman 1995) Specific cognitive skills such as analyzing can be taught with focused short term exercises, but meta-cognitive skills require longer less-constrained projects, as students need to adapt strategies to new situations.

Overcoming roadblocks

Particularly useful in working with computers are the meta-cognitive *compensating strategies*, or creative ways of getting around a certain lack of knowledge. Overcoming limitations by guessing, rephrasing or re-parsing a question are particularly effective in a quickly evolving field.

A related strategy, *contingency planning*, is an important component of independent projects. Since neither technology nor humans are perfect, we need to have techniques for coping with the inevitable problems. While no one is ever careful enough to avoid some inadvertent data loss, guidance and warnings can minimize the damage. Accepting stumbling blocks as part of the process of development rather than seeing them as signs of failure promotes progress in any pursuit, whether it be weight loss or architectural design.

Addressing learning styles

How a person works and the tendency to use particular strategies, is highly dependent on a student's personality, whether formed by gender roles, cultural norms, or inherent disposition. Classes can be more effective if they address the different learning styles which accompany different personality types. Language acquisition literature explains that personal ways of working can become unconscious beliefs about the right way to learn. (Tudor 1996:50) Therefore, explaining about different learning strategies can help learners see beyond their personal learning styles, particularly since the most successful learners don't rely on only one successful method for study, but rather retain access to an array of techniques to be used as required (Oxford and Ehrman 1995).

While many categorization systems exist, a consistent split is shown between students who concentrate on rules and those who prefer to interact. The former are more analytical and systematic but less adventuresome; the latter are more adaptable but more sloppy. Those enjoying the social interaction of communicating learn faster through more practice. In expressing themselves, they naturally compensate for their lack of knowledge by finding alternative means of expression which may be grammatically incorrect. (Tudor 1996:55,116)

Rule-oriented students prefer more step-by-step guidance while the *results-oriented* students tend to ignore the instructions and work by trial and error. Therefore, in a computer class, the former would prefer explicit tutorials prior to creating compositions, while the latter would appreciate getting to make original work immediately.

Learning Style	**Orientation**	**Appropriate CAD Activities**
Analytical	Structure, Theory, Concepts, Organization	Planning layers, symbols & project files, Decomposing spatial/graphic rules & elements, Comparing and contrasting methods Summarizing principles
Concrete	Direct experience, Practical examples	Observing and copying, making Small group demonstrations, Anecdotes from practitioners
Communicative	Interactive Group process	Buzzgroups, group projects Listservs, newsgroups, video-conferencing Virtual Design Studios
Authority-oriented	Hierarchies Predictability	Structured tutorials, textbooks, Constrained mimetic problems, Lectures

Table 2 - CAD Activities matched to K. Willing's learning styles

For a small class, student self-assessment surveys may be used to target learning activities to the specific profiles as in teaching with Myers Briggs types. (Jensen 1987) As teachers naturally gravitate towards activities according to their own styles and beliefs, using the categories to expand the range of activities can be effective for larger, diverse classes.

Rating exercises according to key characteristics is helpful in matching exercises to learning styles. Some important factors are:

Factors	**Poles**	
Focus	TECHNIQUE how	CONTENT what
Degree of choice	CONSTRAINED descriptive/mimetic	FREE creative/generative
Social	GROUP extroversion	INDIVIDUAL introversion
Orientation	THEORETICAL analytical	PRACTICAL concrete

Table 3 - Factors for analyzing CAD learning exercises

For example, a "kit of parts" exercise can be split into two phases to effectively address first rule-oriented and then results-oriented learners. In the first part, students copy building elements from a respected designer's palette, and then assemble them according to the designer's compositional logic. This mimetic exercise allows them to focus on the mechanics of computer modeling, using simple pieces as a vehicle. In the second part, the students are free to use the elements to create their own compositions and may concentrate more on the content than the technique. If the second part of the problem is done as groupwork, the exercise also bridges the introvert/extrovert split.

Results

While I have not quantified results from the introduction of language learning principles, my students have responded positively to the linguistic analogy. The analogy between learning to use computers and learning a language or musical instrument is particularly helpful because people generally understand that a duration of methodical practice is required for mastery. They can relate personal experiences in other classes with the metacognitive strategies introduced with the projects. The graduate students particularly appreciate being given a framework for their learning and being empowered to take responsibility for their own learning.

V. CONCLUSION

What is more important in the digital classroom than people working with computers is people working with people. Optimizing the learning situation is dependent on first clarifying the group agenda of mastering design media and then maximizing the potential synergy which can emerge through teamwork. Synergy can be encouraged by *representing design media as primarily communication media* and by *teaching awareness of the learning process* as introduced in language acquisition literature.

Focusing attention on the communicative aspect of digital tools can spur new techniques for both autonomous and collaborative learning. When computer methods are viewed as a means of communication, new opportunities emerge for creating interactive exercises such as the Virtual Design Studio. Putting students on both the sending and receiving side of the communicative process engages them in social responsibility and co-teaching. Ideally, socially interactive projects:

1) require "big-picture" metacognitive strategies,
2) apply techniques in realistic situations,
3) address the communicative learning style,
4) involve people of different styles and backgrounds.

Throughout the design curriculum, awareness of the learning process can be explicitly taught in different ways, in different situations. Specific ways to apply these principles and strategies need to be tested and documented at a larger scale in order to refine them into more concrete methods. Language learning literature provides ideas on researching learner-centered methods and making research accessible through taxonomies and illustrated applications.

Why look into learner-centered techniques? Awareness of the learning process can be a positive agent for change. Metacognitive skills require active participation, planting the seed for students to shape their own education. At any time, the changes required in integrating new technology provide an opportunity for improvement to arise from uncertainty. At this particular time, discussion of the 1996 Boyer/Mitgang report has created strong interest in reforming architectural education. Active participation from all involved can produce new possibilities.

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