Systemic Expertise: Instructing Non-Artists on Depicting Human Figures in 3-D

Nick V. Flor
Virtual World Research Lab
Anderson School of Management
University of New Mexico
nickflor@unm.edu

Abstract

I use the theoretical framework of distributed cognition to develop a repeatable procedure that non-artists can follow to model 3-D human figures—manikins—on a computer, which are sufficient for prototyping. The approach was not to train artists to be expert human figure modelers, but rather to derive a distribution of abilities across person and computer such that the system of person-in-interaction-with-technology exhibited expertise. These abilities were discovered though an analysis of two equivalent functional systems: figure modeling on a computer and figure drawing on paper. I report a test of the procedure on a group of non-artists, which yielded a high success rate. This research contributes to our understanding of applying distributed cognition to the design of instructional procedures, and to our understanding of the sciences of the artificial.

Keywords: distributed cognition; science of the artificial; 3-D human figure modeling; virtual worlds.

Introduction

Drawing the human figure on paper is a difficult task, as anyone who has picked up a pencil and tried to draw a figure can attest. Modeling the human figure on a computer is also a difficult task, since it either starts with a drawing of a human figure (Oliverio, 2007; Patnode, 2008; Russo, 2006), or it requires detailed knowledge of surface anatomy (de la Flor & Mongeon, 2010; Ratner, 2009; Spencer, 2010). Moreover, one must learn how to operate a complex 3-D software package.

The general problem is that of representing an imagined human figure in some medium, which requires a complex skillset typically acquired through years of practice. For this reason when there is a task that requires either human or human-like figures, such as an animated movie or a video game, one hires artists who are experts in figure modeling.

The specific research question explored in this paper is as follows: is it possible to design a replicable procedure that *non-artists* can learn in a short amount of time for modeling human figures on a computer? This research contributes to our understanding of distributed cognition (Hutchins, 1995), and the sciences of the artificial (Simon, 1996).

The answer to this question has practical implications as well. We live in a highly networked, digital ecosystem where almost every mobile device, notebook, or desktop computer has a graphics processor capable of displaying 3-d models. There is significant opportunity for designing scientific and educational applications that make use of this capability such as virtual worlds (Bainbridge, 2007; see Figure 1). There are also many individuals that have business and information systems backgrounds that would like to develop applications that take advantage of these 3-D capabilities, but lack the skills in figure modeling. Certainly one could always hire an artist, but knowing how to model figures in 3-D and to model objects generally, allows one to more quickly explore the spaces of virtual world prototypes and possible 3-D representations. Artists can still be utilized later in the process to add finishing aesthetics.

Figure 1. Virtual UNM Campus Developed by the Author on a Mobile Device—Human Figure in the Center

Hutchins (1995, p. 155), provided a guiding framework for answering this research question when he wrote:

> *"…a good deal of the expertise in the system is in the artifacts, (both the external implements and the internal strategies)—not in the sense that the artifacts are themselves intelligent or external agents, or because the act of getting into coordination with the artifacts constitutes an expert performance by the person; rather, the system of person-in-interaction-with-technology exhibits expertise. These tools permit the people using them to do the tasks that need to be done while doing the kinds of things the people are good at: recognizing patterns; modeling simple dynamics of the world, and manipulating objects in the environment" (p. 155).*

In the context of this framework the research question becomes <u>not</u> can we make a non-artist into an expert figure modeler, but rather can we design a system of external implements and internal strategies, such that the system of person-in-interaction-with-technology exhibits expert figure modeling skills?

The Processes of Human Figure Modeling and Human Figure Drawing

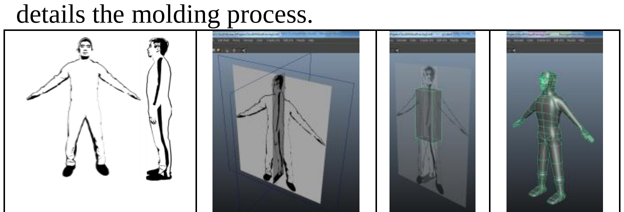
The task of modeling a human figure on a computer consists of a person (the modeler) and the computer running the 3-D modeling software. The challenge is to discover a distribution of abilities across person and computer, which allow a non-artist to model a human figure in a short amount of time.

A comprehensive cognitive ethnography of the process of modeling and drawing the human figure is beyond the scope of this paper. Instead, I describe the general processes and key representations that occur during modeling, based on my experience building 3-D virtual worlds, as well as working with and observing professional Hollywood modelers, animators, and visual FX personnel, as a faculty member and director of the University of New Mexico's interdisciplinary film & digital media program.

The Process of Human Figure Modeling

The process most commonly used in industry to model human figures is commonly referred to as *character modeling with reference pictures*, although I use the term "3-D tracing" because it is analogous to the technique of placing see-through paper over a photograph and creating a drawing by tracing. The method can be seen in a variety of books including, Guindon (2007, pp. 15-83), Ingrassia (2009, pp. 269-288), Oliverio (2007, pp. 47-323), Patnode (2008, pp. 133-207), and Russo, (2006, pp. 83-152). The general process is as follows (see Figure 2 for depictions of the steps):

1. The modeler first obtains reference pictures. In the movie and videogaming industries, these reference pictures are typically drawn by a concept artist in the art department. The concept artist either draws the pictures on paper then scans them into an electronic format, or uses a paint program to draws them directly into an electronic format. The reference pictures depict front and side views of the character to be modeled, with features lined up in both photos including the top of the head, the waistline, and the bottom of the feet.
2. The reference pictures are then imported into a modeling program. The pictures are placed at right angles to one another, and centered.
3. The modeler adds a simple box to the workspace so that it overlaps the torso in both the front and the side reference-picture views.
4. Finally, the modeler molds the box to the reference drawings—extruding limbs, adding edge loops, and moving vertices so that the edges of the model line up with the edges in the reference pictures. Figure 3 details the molding process.



1. Obtain front and side reference pictures	2. Import reference pictures	3. Add a box covering the torso.	4. Mold the box to pictures

Figure 2. Figure Modeling with Reference Pictures, viz., 3-D Tracing. A modeler (1) obtains front and side pictures of a human figure; (2) imports them into a 3-D modeling program; (3) adds a basic box that covers the torso; (4) molds the box to the pictures.

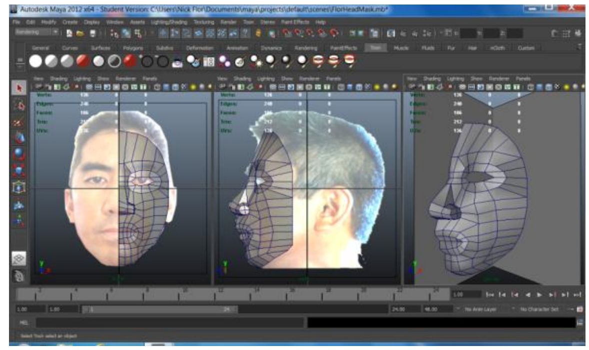


Figure 3. Molding to Reference Images—a time-intensive activity where an artist molds a box or a plane to images, by aligning vertices to landmarks on front and side pictures. In this example, a plane is molded to a face, but the same actions apply to molding a box to a body. The pictures are scaffolds that are removed after modeling is completed.

Abilities and Issues for Non-Artists. For a non-artist to successfully perform the figure modeling process, the main abilities he or she must acquire are to draw the human figure in front and side views (step 1), and to align vertices to landmarks in front and side views (step 4). As mentioned, figure drawing is a difficult skill to learn. Moreover, the alignment process is time consuming. For this reason, figure modeling with reference pictures is not a suitable method for the non-artist.

There is no research that analyzes these abilities and sheds light on developing a new figure modeling process for non-artists. However, an analysis of the figure drawing process reveals abilities that are helpful for developing a new figure modeling process via a redistribution of those abilities across person and computer.

The Process of Human Figure Drawing

The output of figure drawing is both an input to the figure modeling process (step 1 in Figure 2), and is also an equivalent functional system to figure modeling. It is equivalent because both figure drawing and figure modeling result in a representation of the human figure. The difference is the medium—paper in the case of figure drawing, and a computer in the case of figure modeling.

Observations of artists reveal that the drawing of a human figure on paper results from at least three distinct kinds of representations layered on top of one another (refer to Figure 4). These observations are corroborated by information in drawing instructional books (Hampton, 2009, pp. 54-55; Lee & Buscema, 1978, pp. 70-71; Loomis, 1943, pp. 43-45; Reed, 1984, p. 38).

1. The first representation the artist creates is a rough sketch of the figure that depicts broadly the action of the body and limbs. Examples of rough figure sketches include *stick figures*, which use lines to represent the body and limbs; and *gestures*, which are drawings that are completed quickly, in several minutes or less, that are sufficient for a viewer to understand the meaning of the action depicted.

2. The artist then layers a representations consisting of geometric primitives based on spheres, cubes, and cylinders over the rough sketch in order to give the figure both mass and depth (Hampton, 2009, p. 54; Hogarth, 1996, p. 8; Lee & Buscema, 1978, p. 21; Ozawa, 1999; Reed, 1984, pp. 22,24,26). These primitives serve an important function which is known in the psychological literature as scaffolding (Wood, Bruner, & Ross, 1976). As one artist put it: "Square boxes … are necessary for proper depiction of the human form as well. Picture the 3-dimensional human body and think of it in terms of boxes… Once you become accustomed to drawing, there will be no need to draw the boxes, but you should always keep them in mind to make certain you think in three dimensions." (Ozawa, 2005, p. 15)
3. Finally the artist layers representations of muscles, clothing, and shadows over the geometric primitives in order to add realistic detail to the figure. It should be noted that this last representation varied among artists, with some listing it as one representation and others breaking it into as many as three separate representations. Moreover, these are not the only representations that an artist can layer next. For example, if the publisher allows colors, the artist layers color over the detailed figure drawing. However, I list this as one representation—detail—because the general consensus was to layer various kinds of detail over the second representation of the figure-as-geometric primitives.

Representation 1: Rough action sketch	Repr. 2: Mass via shapes	Repr. 3: Detail, which can include muscles, clothing and shading

Figure 4. Figure Drawing as a Sequence of Layering Three Representations (figures adapted from Lee & Buscema, 1978)

The artist's use of these intermediate representations is a good example of the principle of cognitive effort conservation in a distributed cognitive system. Without using these intermediate representations an artist would have to imagine a fully-detailed figure mentally and then draw it. This kind of imagining is a computationally-intensive process for skills like perspective. Instead, when using intermediate representations, an artist can work on different aspects of the figure in smaller more manageable steps, which then serves as a kind of guiding framework for adding more complexity in subsequent representations. In particular, the rough sketch allows the artist to focus on depicting the meaning of the pose. Once complete, this rough sketch serves as a framework for the piecemeal addition of body masses with depth using simple boxes, cylinders, and other geometric shapes, which are easier for the artist to draw in perspective than actual body parts. Once the figure with mass and depth is completed, the basic geometric shapes serve as a framework for the piecemeal placement of muscles, clothing, and lighting details. In this manner the use of intermediate representations changes the task from a detailed thinking then drawing task, into an easier and incremental looking and drawing task.

Abilities for Non-Artists. The observable representations are produced by specific abilities, which in the case of figure drawing on paper are located mainly in the head of the artist and that take many years of practice to develop. According to Loomis (1943), the fundamental abilities required for human figure drawing include "proportion, anatomy, perspective, value, color, and knowledge of mediums and materials." Briefly, an artist uses *proportion* ability to draw body parts in the proper, aesthetically pleasing, sizes relative to one another (Repr. 1). Ability in *anatomy* is used to detail the surface of the body as influenced by the underlying skeletal and muscular structures (Repr. 3). *Perspective* ability allows the artist to draw the body parts from different observation points and with *foreshortening* (Repr. 2), where body parts that are closer to an observer appear bigger than those parts that are further away. It is important to note that foreshortening is the single most difficult ability for drawing figures (Hogarth, 1996, p. back cover). *Value* skill is used to apply the appearance of light and shading to the figure (see last image in Repr. 3). *Impact* is the ability to draw figures in poses that are visually interesting (Repr. 1; Lee & Buscema, 1978, p. 60). Finally, knowledge of mediums and materials is an operational skill—the ability to use paper and pencil or other media and instruments for drawing. Figure 5 depicts the abilities needed for figure drawing on paper.

Figure 5. A Visual Depiction of the Abilities for Figure Drawing.

Redistributing Abilities,Manikins & Satisficing

All the abilities for drawing a human figure on paper, with the exception of proportion, are difficult or time-intensive for an individual to learn.

However, when modeling a human figure on a computer one can have the computer perform most of the difficult abilities, including rendering the figure with the proper perspective, with the proper shading (value), and with color.

The problem of learning anatomy remains, but one can satisfice and remove anatomical detail as a goal, yet still produce human-like figures that are useful for virtual world prototyping. This is not without precedence in figure drawing or animation. Both artists (Loomis, 1943) and animators (Williams, 2001) emphasize the use of manikins (similar to Figure 6), devoid of anatomical detail, for prototyping poses or movements. Detail is added only after the poses and movements have been worked out.

When anatomical ability is removed as a requirement, a non-artist need only learn proportion and impact to model human-like figures on a computer. Like in drawing and animation, detail can always be added later to a manikin. Figure 6 depicts a distribution of abilities suitable for a novice to model 3-D figures on a computer, and where the computer does the more difficult representational abilities.

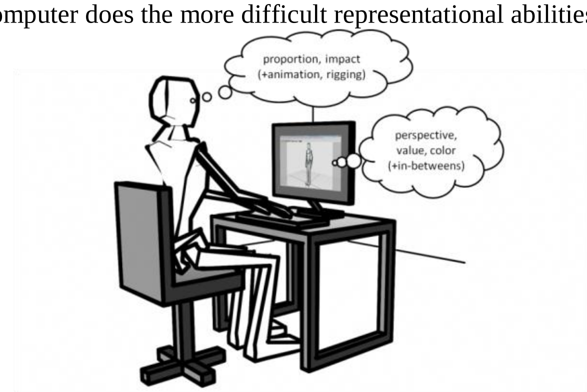


Figure 6. A visual depiction of the distribution of abilities needed to model figures for *prototyping* purposes. Abilities in parentheses are added abilities that are not part of the figure drawing skill set (not covered in this paper)

A Procedure for 3-D Figure Modeling

The redistribution of abilities as depicted in Figure 6, changes the task of modeling a human figure, from drawing and molding boxes to reference pictures (see Figure 2), to the easier task of creating body parts in proportion. The values for the following procedure were derived from the body proportions specified by (Hamm, 1963).

3-D modeling is an activity where an individual creates representations of real or imagined things—that appear to have width, height, and depth—using a special kind of computer program known as modeling software. Popular examples of modeling software include Maya and 3ds Max, both by Autodesk Corporation. The representations are known as models, and the person that creates them is referred to as a modeler.

There are two basic ways to model, using polygons or using curves. This instruction covers polygon modeling—the most popular kind of modeling for games and virtual worlds. Using polygon modeling, the modeler starts with a basic object — e.g., a cube, sphere, or pyramid with a certain *width* x *height* x *depth* and with a certain number of faces — much like a sculptor starts with a lump of clay. The modeler then molds this source object into a target object using the operations of moving, cutting, extruding, wedging, merging, deleting, and mirroring, which are applied to the object's vertices, edges, and faces.

Part 1. Creating the Body

To create a body (Figure 7): (1) Create a cube that is 1x2.5x1 units with 2x5x2 faces; (2) Wedge the top back face 45 degrees, yielding an arm face; (3) Move the outer-bottommost edges .1 units in the x direction yielding a leg face; (4) Extrude the arm face 2.5 units, tapered by .1 units; (5) Extrude the leg face 2 units yielding a thigh; (6) Move the thigh face's inner-bottommost edge +.1 units in the x-direction; (7) Extrude the thigh face 2 units, tapered by .1 units, yielding a calf; (8) Move the middle back vertices to a z-value of zero and merge the overlapping vertices, yielding a back wedge; (9) Mirror to see what the completed body will look like; (10) Save file.

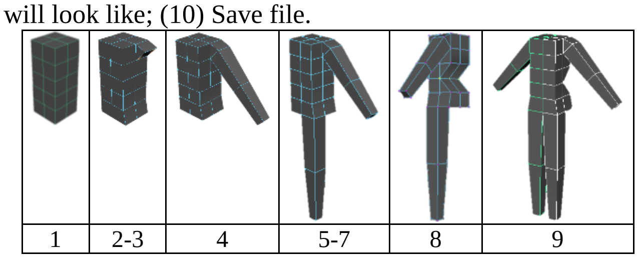


Figure 7. Modeling the Body (see text for explanation)

Part 2. Creating the Hand

To create a hand (refer to Figure 8): (1) Create a cube .5x.125x.5 with 2x1x4 faces; (2) Wedge the thumb face 30 degrees; (3) Inset the stubs .01; (4) Extrude the fingers .5 with 3 divisions; (5) Extrude the thumb .25, then .125; (6) Move back the pointer and ring finger .0625 and move the pinky back 0.125; (7) Move the pinky joint edges back -.0625 and the middle finger joint edges up .0625; (8) Remove the back edges and vertices; (9) Move in the wrist edges inwards by .1; (10) Save file.

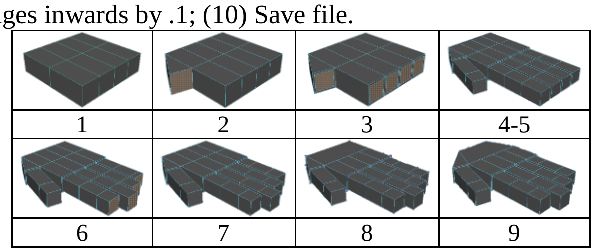


Figure 8. Modeling the Hand (see text for explanation)

Part 3. Creating the Feet

To create a foot (Figure 9): (1) Create a cube that is .5x.25x1, with 1x2x2 faces; (2) Merge the toe vertices down; (3) Move the ankle sides in by .1, and the front ankle by .2; (4) Extend the toes by 1.25; (5) Save file.

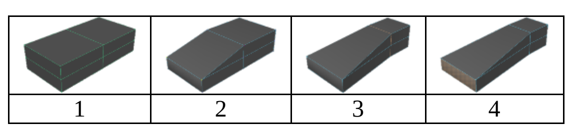


Figure 9. Modeling the Foot (see text for explanation)

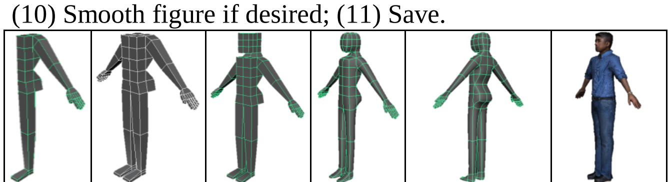
Part 4. Creating the Head

To create a head (refer to Figure 10), simply create a cube that is .7x1x1 with 2x3x3 faces, then save the file. The head can be shaped after it is attached to the body in part 5.

Figure 10. Modeling the Head (see text for explanation)

Part 5. Combining the Pieces

The final step is to merge all the pieces into one (refer to Figure 11). After saving all the separate body parts: (1) Import the half-body; (2) Import the foot; (3) Snap foot to leg; (4) Merge objects & vertices; (5) Import hand; (6) Snap hand to upper limb; (7) Merge objects and vertices; (8) Mirror to get the right side of the body; (9) Attach the head; (10) Smooth figure if desired; (11) Save.



1-7	8	9	10	(reverse view)	Shaped, Textured

Figure 11. Attaching the Body Parts (see text for explanation)

The resulting manikin is suitable for inserting into a game for prototyping purposes, or one can take the time to further shape and texture the manikin to look more realistic (see Figure 11, last image).

Method for Testing the Procedure

Participants

Forty-three students participated in this study. The students came from MGMT 330—Fundamentals of Virtual Business Programming, and none of them had any experience with figure drawing or 3D modeling prior to taking the course, which was a required course for junior and senior level students majoring in management of information systems.

Apparatus

For hardware, students used their personal laptops or desktop computers to run the 3-D modeling software. The software used was Maya 2010, which the students downloaded for free from the Autodesk.com website as part of Autodesk's free software program for students and faculty. All 43 students reported successfully loading Maya onto their personal computers. The University's online instructional system, WebCT, held a link to YouTube tutorial videos made by the instructor on the topic of modeling 3D characters and this video was made available to all students.

Procedure

Students were given a lecture on how to model 3D figures based on the procedure described previously. They were then given an assignment where they had a week both to create a personalized robot avatar and to animate a walk cycle for the robot avatar (see Figure 12 for the written instructions). Note: I used the term "robot" instead of manikin since students were more familiar with the former.

Based on the Professor's Robot as taught in class:
1. Model a robot body in Maya (filename: body.mb).
2. Model a robot head in Maya (filename: head.mb).
3. Model a robot hand in Maya (filename: hand.mb).
4. Model a robot foot in Maya (filename: foot.mb).
5. Personalize your robot body parts.
6. Merge all the body parts to yield a robot avatar.
7. Animate a walk cycle for your robot avatar (filename: robot.mb).
8. Export your walking robot avatar as an fbx file (filename: robot.fbx).

Figure 12. Written Instructions Given to Students

Students received the lecture through YouTube videos that were embedded in the University's online instructional delivery system, WebCT. The total time for the video lectures was approximately one hour. MGMT 330 was a purely online course with no face-to-face component.

Results

There were 43 students in MGMT330. Of these 43 students, 33 turned in a robot, while 10 students did not turn in a robot. Of the 10 students that did not turn in a robot, 7 did not turn in any assignments at all during the semester. Of the 33 students that turned in a robot, 3 did not save their files properly and only turned in an animated skeleton. However, when their work was checked in person, they indeed modeled a robot correctly. If you removed, the 7 students that did not show up to class, then 91.6% of the students successfully followed the procedure for modeling a robot. Figure 13 depicts the robots created by the students.

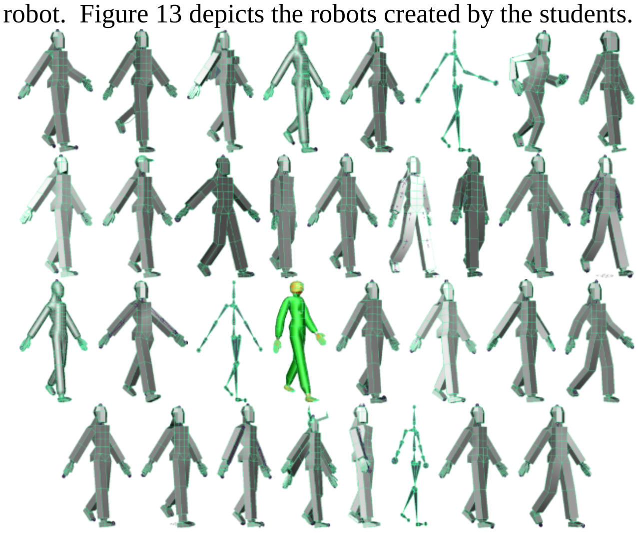


Figure 13. Figures Created by the Management Students

Discussion and Conclusion

The research in this paper presents a repeatable procedure I developed for modeling human figures in 3-D based on a distributed cognition analysis, which can be used to create characters for prototype virtual worlds in academia and industry. Unlike teaching someone how to draw human figures on paper, teaching a person how to model human figures on a computer can be done reliably and in a relatively short amount of time—at least for sophomore-level college students and beyond.

While both drawing and modeling are instances of the general activity of representing human figures in some medium, the specific tools & media change the distribution of abilities needed by the artist. When the tool is a computer running the modeling software, many of the abilities that are difficult and time-consuming for a person to master such as drawing objects in the proper perspective on paper, get distributed to the computer.

While a procedure for quickly modeling character for virtual worlds and games is valuable, equally important is the approach used to design this instructional procedure. Having to design instruction outside of one's expertise is not limited to instructors in academia, but is an activity that both managers and employees may have to engage in especially in a project with new employees using new tools. While instructional procedures are not always written down, they are important to create nonetheless. In situations, where one must design instruction outside of one's expertise, the distributed cognition theoretical framework suggests that it is possible to:

1. Find a reference system of activity that is equivalent in terms of its output to the target system. In the current study, figure drawing on paper was equivalent to figure modeling on a computer. Both activities are known as functional systems in the distributed cognition framework.
2. Analyze observable representations in the reference system, to determine the fundamentals abilities needed to produce the result in the reference system. In this study, the fundamental abilities included proportion, impact, perspective, value, and anatomy.
3. Decide on a new distribution of abilities based on: (a) the goal of the larger system that the target system is part of—or the intended use of the output of the target system; (b) the capabilities of the technology in the target system; and guided by (c) the principle of effort conservation. For figure modeling, abilities like proportion and impact were kept with the person, whereas abilities like perspective and value were distributed to the computer.

What are the limitations of this procedure? Consider that there were two fortunate consequences of my analysis: (1) the abilities that remained after I applied the procedure, i.e., proportion and impact, were easy for a non-expert to master; and (2) the abilities distributed to the computer, such as perspective, foreshortening, and shading (value)—abilities that are difficult for an artist to master when drawing figures on paper—were already implemented by the software.

If after ability distribution, the difficult abilities are not already implemented in the software, someone will have to implement their functionality. And if the remaining abilities are difficult for people to master, then designing an instructional procedure may not be an option.

However, instructors at least have another option to consider in designing their pedagogy. Furthermore, this procedure gives instructors the potential to create novel and possibly innovative forms of instructional material, which provide students the ability to create artifacts that were previously only possible by experts.

References

Bainbridge, W. (2007). Scientific Research Potential of Virtual Worlds. *Science, 317,* 472-476.

de la Flor, M., & Mongeon, B. (2010). *Digital Sculpting with Mudbox.* Burlington, MA: Focal Press.

Guindon, M. A. (2007). *Learning Autodesk Maya 2008:* San Rafael, CA: Autodesk.

Hamm, J. (1963). *Drawing the Head and Figure.* New York: Berkley Publishing Group.

Hampton, M. (2009). *Figure Drawing: Design and Invention.* M. Hampton Publishing.

Hogarth, B. (1996). *Dynamic Figure Drawing.* New York: Watson-Guptill Publications.

Hutchins, E. (1995). *Cognition in the Wild.* Cambridge: MIT Press.

Ingrassia, M. (2009). *Maya for Games.* Burlington: Elsevier.

Lee, S., & Buscema, J. (1978). *How to Draw Comics The Marvel Way.* New York: Simon & Schuster.

Loomis, A. (1943). *Figure Drawing for All It's Worth.* New York: Viking Press.

Oliverio, G. (2007). *Maya 8: Character Modeling.* Plano: Wordware Publishing.

Ozawa, T. (2005). *Let's Draw Manga: Bodies and Emotions.* Gardena: Digital Manga Publishing.

Patnode, J. (2008). *Character Modeling with Maya and ZBrush.* Burlington, MA: Focal Press.

Ratner, P. (2009). *3-D Human Modeling and Animation.* Hoboken, New Jersey: Wiley & Sons.

Reed, W. (1984). *The Figure: The Classic Approach to Drawing & Construction.* Cincinnati: North Light Books.

Russo, M. (2006). *Polygon Modeling: Basic and Advanced Techniques.* Plano: Wordware Publishing.

Simon, H. (1996). *The Sciences of the Artificial.* Cambridge, MA: MIT Press.

Spencer, S. (2010). *ZBrush Digital Sculpting: Human Anatomy.* Indianapolis: Wiley Publishing.

Williams, R. (2001). *The Animator's Survival Kit.* New York: Faber and Faber.

Wood, D., Bruner, J. S., & Ross, G. (1976). The Role of Tutoring in Problem Solving. *Journal of Child Psychiatry and Psychology*, *17*, 89-100.