ISSN 1392-1126. eISSN 2424-6158. 2018 Priedas
DOI: https://doi.org/10.15388/Problemos.2018.0.12345

Ugdymo filosofija

ARTIFACTS, VISUAL MODELING AND CONSTRUCTIONISM: TO LOOK MORE CLOSELY, TO WATCH WHAT HAPPENS

James E. Clayson
American University of Paris
james@clayson.org

Abstract. *Constructionists operationalize a powerful notion they share with constructivists: individual learning is facilitated by building models of specific ideas, concepts, methods, objects, environments, feelings, dreams, memories and sounds using the learner's current stock of knowledge. Constructionists do this by building models or artifacts that can be externally manipulated, interrogated by their builder, and verbally shared with others. Constructionists believe that new knowledge is created during these discussions. Constructionism is rich with heuristic methods for both finding and constructing artifacts and for discussing these artifacts privately and publicly. Constructionists argue that both constructing and discussing are necessary for deep sense-making.*

This paper describes one specific constructionist learning method: visual modeling. It illustrates one educator's approach, developed in the classroom over a 40-year period. It references the relevant literature; describes its pedagogic approach, materials and outcomes; and it offers a step-by-step example of one student's thinking process. Finally, it presents – in appropriate narrative form – 15 arguments why the visual component extends the constructionist project and should be integrated into more educational programs.

Keywords: *constructionism, visual modeling, transformational objects, artifacts, drawing, narrative psychology*

The astonishing reality of things
Is my discovery every day.
Each thing is what it is,
And it's hard to explain to someone how much this makes me happy,
How much it's enough for me.

Fernando Pessoa (2007)

Artifacts

The 'bricoleur' ... speaks' not only with things ...
but also through the medium of things ...

Claude Levi-Strauss (1966)

The finding, constructing, sharing and using of artifacts is central to the constructionist project. Seymour Papert, the primary author of constructionism, argued that learning and sense making are facilitated by constructing personal artifacts that model what a viewer sees, senses, construes, conceptualizes or abstracts when looking closely at physical objects or when thinking about ideas, emotions and bodily feelings. The modeler uses whatever media, materials, tools or notation she has immediately at hand.

Here is how Papert and Harel articulated this notion:

> Constructionism – the N word as opposed to the V word – shares constructivism's connotation of learning as building knowledge structures irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity. (1991: 1)

Edith Ackermann, a Swiss born and educated developmental psychologist, worked with Papert at the MIT Media Lab. She personalized constructionist activities by clearly stating the necessity of conversing with and through constructed artifacts: "Papert is interested in how learners engage in a conversation with [their own or other people's] artifacts, and how these conversations boost self-directed learning, and ultimately facilitate the construction of new knowledge" (Ackermann 2002: 1).

We can think of artifacts not just as descriptions of thought processes but as the process of thinking itself. Therefore, looking at our own artifacts, reflecting on them and discussing them with others is a formal way to think about thinking in a specific context. Papert addresses this in his article about thinking (2005): "You can't think about thinking without thinking about thinking about something". He should have added that we need to think about a *specific person* thinking about something *specific*. Talking to and talking about our own artifacts opens up a kind of self-reflection that allows for our own thinking about our thinking about things we enjoy thinking about. We can thus watch and record how we make sense in specific contexts.

There are other kinds of artifacts besides those constructed by us and others that can also move us to engage, in uncanny and surprising ways, fresh emotional and intellectual activities. This class of found artifacts is generally labelled by psychologists as being evocative or transformational. Sherry Turkle, a sociologist and psychologist, has documented the primal importance of transformative moments in human existence. She has assembled several collections of personal narratives about transformative objects and all constructionists should read these (Turkle 2007, 2011). Christopher Bollas offers the psychoanalytic view of transformational objects (1987). French philosopher Gaston Bachelard (1969) describes how and why we can be greatly moved by objects and physical spaces.

In his emotional telling about a first encounter as a young boy with gears, Papert himself recognized the significance of the found artifact for his later intellectual development. This tale appears prominently in the preface to his most noted book, *Mindstorms* (Papert 1982), and has become a familiar part of the constructionist story.

Papert was raised in South Africa. His father, an often-absent entomologist, gave young Seymour a toy car. This little model car included a functioning differential whose purpose was to allocate the rotational energy from the engine to each of the two rear wheels of the car. Papert was fascinated to discover that the energy distribution from motor to wheels could not be guessed without knowing how the car would interact with its environment. The cluster of gears in the differential became strange and seductive like a complex puzzle to Papert. These differential gears didn't work as he had expected them to work. He had to try them out on his own terms, to play and explore them empirically.

In Papert's telling, he loved to imagine himself as not just playing with the car, or even sitting inside it, but actually becoming one of those gears in the differential, moving as the car moved. When Papert later encountered algebra for the first time he tried to visualize equations as physical sets of interacting gears. The interaction games with that toy car proved pivotal in allowing Papert to come upon and to explore a number of powerful ideas that he developed later as an adult: simulation, emergence (Resnick 1994), debugging, body syntonicity and restructuration (Wilensky and Papert 2010). He said that he "loved his gears". He hoped that students could use his *Logo* computer programming language to build artifacts that they would love too.

Artifact creation and interaction encourages a variety of different kinds of emotions and learning. Different people interact differently with similar artifacts and each person may describe, interpret and model these relationships in their own unique way. Constructionists value and encourage the explicit display and documentation of such epistemological pluralism (Turkle and Papert 1990).

Papert was a gifted mathematician and his reactions, explorations and the language he used to describe his connection to evocative objects is within that tradition. But as I discovered in teaching liberal arts students, contact with transformational artifacts can certainly enlighten those who are not at all mathematical – who come from the arts and humanities – motivating them to actively explore new ideas in their own fields.

Relationship Between Found and Constructed Artifacts

There is an important relationship between found and constructed artifacts. Personal fascination and play with or within specific artifacts, such as paintings, trees, flowers, games, music scores, dance movements, work spaces, cars, ships, beaches, canyons and our own back yards can encourage us to build models of these objects just like Papert did. The ability to build artifacts of artifacts is, of course, what deep learning is about, and can boost personal agency.

The remembrance of these activities is in itself agency enhancing. It is powerful to remember past epiphanies, past breakthroughs. This, I think, is why Papert introduced his own gear story to us. He offered the reader this implied plea (my words): "Look at what happened to me when I played with loved artifacts. Look what happened to you when you did the same. Remember and savor those times."

Christopher Bollas talks at length about our life-long need for transformative objects (1992). He suggests that we reconnect with past events by looking more deeply into them and by modeling them imaginatively. He argues that re-appreciating past connections will open us to finding new transformational events.

Still another perspective comes from the Canadian computer scientist, David Kirsch (2006: 1), who explores the complementary notion that "much of culture's history – its knowledge, capacity, style, and mode of material engagement – is encoded and transmitted in its artifacts. [They] transmit cognition, they help to transmit practice across generations, shaping the ways people engage and encounter their world".

Visual Modeling Links Objects to Learning

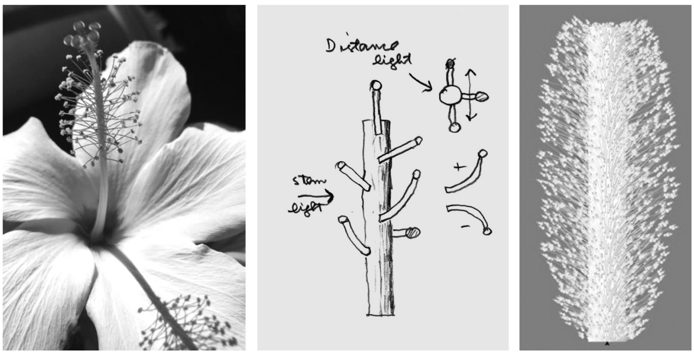
My course in visual modeling (Clayson 1985, 2007, 2008, 2015) is structured around a series of exercises that encourages students to embark on individual computational explorations looking closely at physical objects meaningful to them. The central task is to construct an artifact of evocative themes seen in objects, while the method mixes traditional modeling media words, diagrams, sketches and journals or notebooks with computational tools.

My goal is for each student to create a personal story that encapsulates their sense-making. Doing so also brings about important side effects: the model builder gets a rigorous introduction to situational design and computational literacy done through excursions into art history.

I've called this modeling process "radical bricolage" after Levi-Strauss's use of the French term "bricolage" (1966). I encourage students to use a variety of tools and approaches drawn from what they already know, what they have at hand. *Everything* is fair game. I add the term "radical" to emphasize the "everything". Using one tool or one idea is hardly ever enough. A collection of approaches is generally more useful than any single one.

Each tool contributes in different ways to how we come to grips with describing what we see in objects. Modeling provides a series of linkages. The sum of these links adds new meanings to the target object and to the tools and techniques that were used in the process. Tools and objects inform each other. In the words of cognitive scientist, Marvin Minsky (1987: 64), "the secret of what anything means to us depends on how we've connected it to all the other things we know". Building models generates connections.

Radical bricoleurs build models through accretion. Each step is taken quickly using knowledge and tools at hand. We revise at each step by *watching what happens* when new ideas come to us independently or with discussion with others. We hope that models can extend our view beyond that of *looking closely* at one specific object. We play with models to push themes beyond the source of those themes. The excitement of doing this encourages us to look more deeply at all physical objects.



Example. ***A student constructs a personally meaningful visual artifact. Original flower artifact, sketch of selected themes, the rendered artifact.***

Student C loves Hibiscus Flowers

C moved to southern California from Chicago. Los Angeles was a vivid transformational time for him. The flowers that he remembers growing in his garden symbolize this exciting period. He photographed these flowers and wrote descriptions of what he liked about them. He dried and pressed them into his journal as first steps to building his computational model.

Next, Student C began the modeling exercise with a word description of his hibiscus flower:

> The central stamen really interests me. I want to look more closely at that shape and the collection of tiny filaments that seem to shoot out from it and give it its extension. I rotate the flower in my hands; I see a complex tree form.

C used my turtle graphic extensions to *Python* (Clayson 2015) to scrutinize his hibiscus flower themes. He used sine and cosine notions to structure filament placement and color selection. C had forgotten much of his high school algebra, geometry and trigonometry and he was thrilled to see that he could relearn vaguely remembered notions and apply them quickly to specific tasks. He went on to model other aspects of his flower and generated many images. This led my student to modeling color computationally. I suggested that he consult Joseph Albers' classic text (2013) as a guide.

C assembled all these explorations into his journal. His narrative links photos, sketches, words, diagrams and computer programs and experiments. This *narrative is the artifac*t. The computer codes he composed are only a part of the artifact and are meaningful only as they fit into the whole. A narrative wraps up the pieces. Narrative can be manipulated, re-thought and shared with others. In the words of narrative psychologist Brian Schiff (2012: 37), narratives "can be taken as an object and analyzed. They are en-textualized in speech or action and can be commented on, turned to in conversation and taken to other contexts".

Most importantly, and as a result of this hibiscus modeling exercise, C reported that he had begun to look at other flowers (and trees, plants, shrubs) and colors everywhere in ways that surprised him. Through computational modeling he had found new ways of seeing things.

There is joy in building something that is authentic and meaningful to us. Computational artifacts like C's can be "held" and "toyed with" much like concrete analogs. Levi-Strauss describes the sensation:

> In the case of miniatures, in contrast to what happens when we try to understand an object or living creature in real dimensions, knowledge of the whole precedes knowledge of the parts. And even if this is an illusion, the point of the procedure is to create and sustain the illusion, which gratifies the intelligence and gives rise to a sense of pleasure, which can already be called aesthetic on these grounds alone. (1966: 23f)

The Relevance of Visual Modeling to Current Educational Concerns

General education

My approach to visual modeling operationalizes many of the features Kalantzis and Cole (2012) call the multimodalities of "new education". They discuss some big ideas that are especially relevant to my own work:

- teachers must acknowledge not just differences in cultural and class

backgrounds of students and their future vocational goals, but also fundamental differences in their epistemologies (2012: 9);
- “the source of valid knowledge is no longer primarily linguistic. <…> It is also multimodal, where the visual (diagram, picture, moving image), gestural, tactile and spatial are considered to be just as valid knowledge sources as writing” (2012: 71);
- formal methods of recording how students think about their own thinking is an effective way for sharing knowledge making with others and developing one’s own learning strategies (2012: 71);
- all teaching must be both multimodal and multidisciplinary (2012: 294);
- teachers should appreciate the tools of social science in addition to those of their their major discipline (2012: 31).

Kalantzis and Cole (2012) also include an excellent and comprehensive bibliography that reviews current research and is thus a helpful introduction for readers new to these ideas.[1]

Design and art education

Mike Tovey (2015) has edited a useful compendium on design pedagogy that reviews design education at general and professional levels in institutions around the world. Several of its primary findings would seem to validate my visual modeling project and argue for the benefits of expanding visual thinking in education generally. For example, contributor Eddie Norman (2015) has written: “what cognitive science has done is to show conclusively that designerly thinking and actions are features of the mental activities of all humans” (2015: 70). Other research discussed suggests that the most effective way to extend and enhance these natural skills is through problem-based, multimodal, real-world exercises rather than isolated skills-based work.

Several other contributors – Linda Drew (2015), Seymour Roworth-Stokes and Tim Ball (2015) – place special importance on the development of students’ narrative skills. And Tovey, in his concluding chapter, reminds us that

> In order to establish their identities as designers they will need to be able to tell their own stories. Such identities will relate to the particular signature characteristics and will depend on their having travelled through a transformative learning experience … (2015: 157).

Drawing and drawing research

There is a vast literature in this area. I have selected a few publications that highlight results of contemporary research into drawing and its application to general education.

Fava, Kantrowitz, et al. (2014) edited a special issue of TRACEY dedicated to “Drawing in STEAM”. The authors explain that

> In 2012, we invited practitioners from a broad range of disciplines to share experimental and innovative uses of drawing and discuss the broader implications of such developments. We were particularly interested in uses of drawing outside of art and design, and the potential for creative exchange and blurring of disciplinary boundaries… Our theme ‘Drawing in STEAM‘, was inspired

[1] The linked website also offers resources and food for thought: http://www.newlearningonline.com.

by the STEM to STEAM initiative, championed by Rhode Island School of Design and U.S. educators who advocate for the infusion of Art and Design into STEM education.

Goldsmith, Simmons, et al. (2014) speak specifically to "how visualizing and drawing – both fundamental tools of the artist, designer illustrator, and architect – can be critical in STEM disciplines". Kirsh (2009, 2014) addresses the more fundamental issue of how sketching supports thinking and learning techniques.

Ionascu and Rohr (2016: 7), in their editorial to a new journal devoted to drawing research, discuss new studies that show the power of drawing both within its traditional sphere of the studio arts and architecture has especial cognitive advantages elsewhere in general education.

My Own Visual Modeling History and Narrative

Each of the courses I developed grew organically from my own personal experiences, professional and intellectual development. They also changed over time in response to classroom interaction and a desire to explore new approaches.

Following graduate school, I worked in industry for ten years as director of an operations research (OR) group. After I moved to France, I discovered the power of imagery and visual literacy. I managed an art school in the south of France for five summers. This eventually informed my whole teaching approach and led to a radical reexamination of pedagogical approaches. I was already in my early forties when I was hired by the American University of Paris (AUP) to teach OR.

I found my AUP students to be highly motivated, extremely verbal in several languages and street wise. These operations research students – who were economics, business and computer science majors – had taken scores of separate courses but few truly interdisciplinary ones. They had difficulty integrating the quantitative with the qualitative and breaking large problems down into the smaller parts that could provide a starting point for coming to grips with the whole.

Students didn't know how to diagram relationships since they had no visual vocabularies. Few of them had ever taken a studio arts class. They weren't yet in possession of personal repertoires of problem-solving techniques. They didn't know the value of speaking with others to help clarify ambiguous tasks and, when this did happen, they didn't yet appreciate the importance of recording verbal clips of shared insight. They were totally unaware that just talking could become a starting point for figuring out difficult problems and that often they didn't need new tools to do so.

One day, Roger Shepheard, the director of Parsons School of Art in Paris, told me that his painting and drawing students unlike my students had no trouble in talking about ambiguity and multiple viewpoints. They all kept journals in which they recorded talk, ideas, diagrams, sketches, i.e. their work process. They loved deconstructing and reconstructing, cutting and pasting. But, he said, they were distrustful of and resistant to a more structured plan. For them everything seemed open for further exploration. But Roger wanted these art students to achieve some closure.

That's when Roger and I devised a plan for putting our students together in a single team-taught course and to watch and assess what happened. We paired my economics, business and computer science majors with Roger's art students and called our experimental course *Problems in Visual Thinking.* The central constructionist twist and pedagogical engine for this course was model building with *Logo*. We taught this class for 5 years and it became the basis of my book on problems in visual thinking (Clayson 1988).

After this stimulating initial experience, I revised and extended my visual modeling ideas for a team-taught course with AUP colleague and artist, Ralph Petty. We agreed the course would be open to AUP students from any discipline, including math, social sciences and literature. Our collaboration lasted 10 years from 2000 through 2009 (Clayson 2007, 2008).

The seven most important lessons that I learned during this time were:

(1) Visual modeling works best when students focus on looking closely at specific concrete objects or environments that they have some strong attachment to.
(2) Encouraging students to talk about past transformative events in their lives can suggest good modeling sites.
(3) Lessons about design principles and the effective application of and the re-learning of past mathematics doesn't happen automatically. Individual instruction based on specific student interests and needs is not just useful but pivotal. Structured class discussion drawing out lessons from individual students and focusing on their narrative building is mandatory.
(4) The art of journaling is developed only under constant tutelage from the instructor. Good examples of modeling narrative must be available and discussed when appropriate.
(5) The instructor must always do the exercises and share their material to compare with others and to illustrate the multiplicity of approaches.
(6) Constructionism has always been overly concerned with mathematical and computational literacy at the expense of kindred constructivist disciplines: the cognitive and social sciences, the studio and design arts, and those disciplines that emphasize body syntonicity: dance, theater, music and poetry. Contact and exchanges with colleagues in these other disciplines helped my teaching immeasurably.
(7) Finally, constructionism and instructionism are not mutually exclusive pedagogical methods. They must be combined like all other modes of thought and description. Visual modeling must be based on a multimodality of learning, teaching and narrative tools and methods.

In 2015 I was invited to teach my visual modeling course at Deep Springs College in California. Because *Logo* had fallen out of favor by then I built, with the help of colleagues from Comenius University (Slovakia), a number of *Python* modules that could accommodate my own visual and constructionist style. The exercise in translating hundreds of procedures from *Logo* to *Python* was a constructionist exercise in its own right.

Looking Closely at What Happened Over 40 Years

Throughout my teaching I encouraged students to look more closely at favored objects in their lives and to record what happened and what they felt when they did this. Computational methods were the necessary catalyst for this activity, but they were not sufficient. In the end, it was the critical mixture of qualitative, visual and quantitative methods that lead to students' seeing more clearly. Seeing clearly provided them an intense emotional and intellectual satisfaction that lasted long after the course was over.

I've already discussed the importance of narrative. Here, I have distilled 15 arguments culled from my own teaching journal that highlight why the act of deep seeing is primal. I offer them in a *narrative style* that is consistent with my constructionist philosophy.

Fifteen Arguments for Doing Visual Modeling

1. Aesthetic argument. When we model an object in order to bring it down to a size that we can hold, to view it from all sides, this can give us enormous aesthetic pleasure. Whether the model is a miniature flashing Eiffel tower, a ship model, an embroidery, we can sense its wholeness without dwelling on individual parts. The model, of course, will be an abstraction, a simplification of the whole. Levi-Strauss (1966: 24) talks about turning physical dimensions into "intelligible dimensions". We could also call them meaningful dimensions. Seeing one object more meaningfully through our interaction with it is a skill that can easily be transferred to other objects (Bateson 1972).

2. Design literacy argument. Two-dimensional graphic design explores the aesthetic, emotional and communication inherent in compositions of lines, shapes, typography, signs, symbols, color, texture and depth cues placed on a canvas, page or website. Typically, basic design courses introduce design theory through a structured set of exercises resembling my own constructionist approach (Wilde 1991). Unfortunately, most university students do not have the opportunity to learn anything about art or design concepts, nor to gain insight into how design might be useful if applied to other fields. Visual modeling, properly structured, can offer a crash introduction to the language and tools of design.

3. Situated computational thinking argument. Proponents of computational thinking often talk about the "power of abstraction" that is implicit in computer programming. I have found that this powerful idea resonates best when abstractions from one medium are compared with those from another. The sketch of an object, or a poem based on it, after all, are abstractions. But it is the comparison between the drawn and the spoken and the programmed abstraction that is the essence of visual modeling.

The public domain book *How to Think Like a Computer Scientist* (Wentworth 2018) offers a handy introduction to computational thinking with *Python*. The question is, handy for whom? It has been useful to me because I trained as an engineer, have studied computer science, have learned to program in many different languages and have taught applied mathematics. In other words, it is useful because I already know how to think like a computer scientist. This is not the case, however, with most of my visual modeling students. This book, while useful to me, is less useful for my liberal arts students. But this is not a problem because my students already possess a personal epistemology. They want to find and use tools that they feel comfortable with that can immediately help them to get on with their own modes of inquiry (Minsky 1987, Kelly 1955). Students don't want to have to become someone else first and why should they?

What are some of the simpler more accessible computational tools these students might find useful? Design manipulations – using deconstruction or reconstruction, replication, scaling, generating random components, perspective and color operations – are one example.

Another example is found in recursion, for example, which appeals greatly to some non-technical students, especially artists, who want to immediately play with it. Recursion seems to strike at something they feel emotionally at ease with. Linking design and illustration tasks with computer constructs that operationalize these tasks extends the meanings of both design and computational tools. New tools can suggest new design approaches.

4. Simulation argument. Another big idea from computer science that stands out in my mind is simulation. Simulation is the act of turning ideas into computer code that can be manipulated and experimented with. Students can actually watch what happens when they do this and are therefore motivated to continue their explorations. I have found that working in an environment of visualization makes simulation even more potent. Students see what a computer model of an idea means by watching what it does. And they don't have to be computer experts to do so. "Debugging" refers to how simulation helps us straighten out *our* thinking.

5. Body syntonicity argument. The word syntonicity was coined in the 1800s to describe alternative musical tuning systems. When two instruments were heard to be in harmony with each other, they were judged to be syntonic. This meaning was later extended to describe individuals whose emotions were in tune with their environment. Freud extended syntonicity's use to his system: a person's manner was ego-syntonic if it supported the needs and desires of their egos.

Papert's incorporation of turtle graphics into his *Logo* language was intended to open young programmers to affordances in tune with their body language and to radicalize the way geometry is taught. I have found that basing my visual modeling classes on turtle geometry does radicalize the way geometry is remembered and rethought for use in physical tasks. The real value added seems to be the pleasure of being able to do this, to remember, to rethink and use something only vaguely remembered. There are, of course, other body sources of knowledge that Papert did not seem much interested in: the eye, ear, hand and voice (Arnheim 1969). In visual modeling these resources all have a role to play, and all must be called upon in order to look closely.

6. Meaning-making bricolage argument. Levi-Strauss (1966) used the term "bricolage" to describe a direct approach to problem solving, repair work and thinking. Levi-Strauss studied pre-modern societies, but his ideas are remarkably contemporary.

The bricoleur acts quickly using notions, improvisations and tools that are already at hand. Speed is often important. We can think of the bricoleur as a repair person who carries around a bag of tools that can be used on the spot. The repair plan often emerges from the doing itself, through iteration.

Visual modeling uses bricolage tools often overlooked in education: learning to talk and write rapidly about what we see, making quick diagrams of the structures we observe and the ideas we have about them. I discovered that when students act like the bricoleur, and have to improvise quickly, pieces of remembered algebra, geometry and trigonometry often pop out. They will test if and how these mathematical notions might help in solving some visual task. Often this means relearning the half-remembered math. Often it means learning the math for the first time, but in a context meaningful to the student.

7. Thinking journal argument. Unless meaning-makers can watch themselves in action, see how they dialogue with themselves, view how they share their own meaning-making activities with others, how can they study themselves? Visual modeling requires that modelers keep a journal of their modeling activities: the words, sketches, codes, code play and code change. Journaling then is the trace of these activities, a trace of thinking. We need to catch and record these acts of thinking so that we and others are able to reflect upon them later (Clayson 2015).

8. Concreteness argument. Perhaps the most obvious feature of visual modeling – the sheer physicality of the target subject – is not fully appreciated. The target is viewable; the modeling methods are viewable; the images generated by the modeling process are viewable. Visual comparisons between the target subject and the model are easy to make without a lot of abstract analysis. This viewability is not so true in math courses. Tangibility encourages fuller emotional and intellectual participation from students having different skills and interests

9. Not-like-other courses argument. Papert warned about the difficulties of inserting *Logo* constructionism into traditional academic courses, especially mathematics. He therefore advocated doing something totally new. In the early 1980s when I first taught formal computational modeling, I deliberately refrained from labelling it either a math or a computer science course. Instead I focused on the design aspect of visual modeling, a non-traditional academic approach. I structured and marketed these courses to appeal to a variety of different student majors.

10. Emotionally comfortable and vocational argument. Visual modeling is a multidimensional introduction to design theory, computational modeling, formal reflection on thinking, careful and clear observational techniques and effective journaling. I think It is important to note that a visual modeling approach also seems to help many students who have suffered unhappy experiences with math courses in the past. With visual modeling they gain math agency because they are able to use mathematical notions to see and find new meaning in their own physical worlds. The freedom and ease of mixing personal math knowledge with other disciplines is an extremely useful vocational outcome.

11. Computational aesthetics argument. Visual modeling introduces the notion of looking closely at works of art, as well as other objects around us, by modeling their themes algorithmically. But finding characteristic themes requires learning a new vocabulary appropriate for describing and interpreting art. In my classes we show each other specific examples, often using museum postcards, from different abstractionist schools of painting and learn to describe them. Various methods for deconstructing or reconfiguring objects into themes are portrayed and discussed. Alternative approaches to modeling similar objects taken by different artists are examined. Using cubist, impressionist, fauvist, pointillist, supremacist or abstract expressionist techniques can suggest different and surprising ways to configure and display even the most mundane of objects as well as seeing the surprising complexity of all shapes (Clayson 1985, 2007, 2008, 2013). I argue that looking closely at works of art, both abstract and realistic, can affect how we look at and relate to objects around us. The reverse is also true.

12. Tricking the ego argument. We see what we expect to see and usually that is what we have already seen before. We scan fields of things, but often do not look closely at individual items, especially if they are thought to be already familiar. We may hesitate from taking a visual arts class because we think "I can't draw" because we have never learned how to slow down enough to look at things closely and carefully. Yet everybody is capable of drawing, so why are we so hesitant? It's because we hear the little voice of our ego warning us that the experience might be embarrassing.

Visual modeling offers an alternative and tricky means of settling down and looking at concrete things that is not like other visual arts. Paradoxically, it shows us that in order to slow down we have to work faster. We are drawn-in to the object-subject without realizing it: by talking very quickly about what we see, writing about it, sketching, coding and playing with that code. Fast, without reflection. Something surprising always happens during this experience. Ironically, using such a simple and limited medium as turtle graphics, actually gives us a freedom and willingness to draw that more sophisticated tools often inhibit. It is exciting and empowering, like the child's uninhibited use of crayons on blank paper. The slowing down trick is accomplished by working fast with what we have at hand. Sketch fast, talk fast; then code it; not the reverse. The trick is to break the pattern of seeing only what we anticipate seeing. Visual modeling is full of tricks and surprises, so the results cannot be anticipated.

13. New transformational objects argument. Papert (1982) concentrated on telling us about his own transformational experience with model car gears and how he used *Logo* to seek out other transformational occasions. But he didn't say why it might be important for each of us to recall our own transformative events and how we might draw energy from this. The already referenced Christopher Bollas (1987, 1992) argues convincingly that people are designed to continue searching for transformative objects over their entire lifetime. Unfortunately, the frenzy of our adult lives often inhibits us from coming upon them. Visual modeling helps restore students' ability to find and exploit transformative objects in their local surroundings for personal pleasure and development.

14. Different modes and different points of view argument. Good problem solvers know how to structure and then restructure situations in alternative ways. Statisticians know that multiple approaches, each based on unique methods, is the creative way to explore a data set. Similarly, art students know to move around a figure or still life, sketching and appreciating the model at each location before they settle down to work in more detail. Each perspective offers its own rewards as does using different drawing tools such as pencil, pen, chalk or charcoal. Explorations with different modes and points of view allows both statisticians and art students to watch what happens.

15. Meta-artifacts argument. I have seen the ways that building models (artifacts) of loved objects encourages deep learning and gives enormous personal satisfaction. But I have also seen how students attempt to link both built and found artifacts into a larger meta-artifact. With encouragement, they sometimes go on to narratize their meta-construction. I have come to believe that the discussion around how we link our personal meaning-making artifacts together becomes our life story.

Meta-Texts versus Texts

Constructionists talk a lot about how we learn: is knowledge transmitted or is it constructed? Most of the constructionists I know favor a far more nuanced approach to this discussion. Whatever knowledge building (acquisition) is, it is certainly not explainable in binary terms. Such reductionism just doesn't suit human diversity. A variety of learning modes is always preferable. Throughout my teaching career I have found that a combination of instructionist and constructionist approaches works best. This seems natural to me but is not always natural to my students – especially because of the dominance of instructionist education in the world and resulting aversion to ambiguity and risk.

To address this student anxiety, I have always tried to show by example why and how different approaches to a single problem may all be useful, each in its own way. Thus, for every course I teach, I write what I call a meta-text – as opposed to a standardized text. My meta-text is designed to show how I myself have gone about learning the material in our course and suggests that students use it as a starting point to create and record their own experiences too.

The most important text in many subjects is the one written by the students themselves in their own language and style. As a constructionist I know that agency is best gained by constructing a written document that can be read and modified over time. The student as author is free to make additions and changes to their own text, and in my classes, they are required to share this record with others who are also writing their own texts.

This record-keeping is what I mean by "journaling". But how do students get started with such a journaling exercise? Not, I think, by following a fixed set of rules, but rather through examples in the context of the course material being explored. We talk in class about the different ways of doing this, and we check in throughout the semester to compare notes. Therefore, my meta-texts include my own journal entries of how I explored the same task that I set for my students, along with illustrations of other approaches that may also represent student work.

Conclusion

In addition to reviewing some of constructionism's foundational ideas and reviewing the literature, this paper has described my constructionist teaching methodology in the form of fifteen arguments. The approach and lessons learned have emerged over 40 years of teaching mostly humanities and social science students in a liberal arts setting. During this time, however, most of my constructionist peers were preoccupied with teaching math and science students. In such a community, the introduction of visual thinking and journaling as essential elements of learning have made me a bit of an outlier. But I stand by my approach with its emphasis on visual modeling, and I am happy to see that an increasing body of research seems to support what I as a teacher had learned empirically.

Looking back, I see that my journey has been surprising, taking unexpected turns and new directions. I certainly wasn't planning to become a teacher. At each new juncture there was a transformative event or object – teacher, book, conversation or conference – that pointed the way forward. And always, it seems, there was a constructionist thread: a need to explore, to learn, to model and to build a common project along with my students. The relationship has been reciprocal: we have all learned from one another, but each in our own way.

In today's world there is a tendency to look without seeing. We are too busy, moving too fast, too overstimulated by digital interfaces and gadgets. This is such a pity. Seeing is not only one of life's great pleasures, but also a powerful instrument for learning and understanding. We need to remind ourselves that in human evolution, the eye, the hand and the brain developed together. This paper has proposed one way that visual literacy can inform, augment and enrich our educational enterprise.

REFERENCES

Ackermann, E., 2001. Piaget's constructivism, Papert's constructionism: What's the difference. *Future of Learning Group Publication* 5(3): 438.

Albers, J., 2013. *Interaction of Color: New Complete Edition*. London: Yale University Press.

Arnheim, R., 1969. *Visual Thinking*. London: University of California Press.

Bachelard, G. and Jolas, M. (translator), 1969. *The Poetics of Space*. Boston: Beacon Press.

Bateson, G., 1972. *Steps to an Ecology of Mind*. London: University of Chicago Press.

Bollas, C., 1987. *The Shadow of the Object: Psychoanalysis of the Unthought Known*. London: Free Association Books.

Bollas, C., 1992. *Being a Character: Psychoanalysis and Self-Experience*. New York: Hill and Wang.

Clayson, J., 1985. *Visual Modeling with Logo: a Structured Approach to Seeing*. Cambridge, MA: MIT Press.

Clayson, J., 2007. Radical Bricolage: Making the Liberal Arts Coherent. In I. Kalaš (ed.), *Proceedings of EuroLogo 2007,* Bratislava.

Clayson, J., 2008. Radical Bricolage: Building Coherence in the Liberal Arts Using Art, Modeling and Language. *International Journal of Education through Art* 4(2): 141-161.

Clayson, J., 2013. Talking Statistics/Talking Ourselves: Some Constructionist Lessons from the Work of George Kelly. *Technology, Knowledge and Learning* 18: 181-199.

Clayson, J., 2015. *A Computational Eye: Visual Modeling with Python*. Bishop, California: Deep Springs College.

Drew, L., 2015. The Experience of Teaching a Creative Practice. In M. Tovey (ed.), *Design Pedagogy: Developments in Art and Design Education*, Oxford: Routledge, 2015, pp. 95-112.

Fava, M., Kantrowitz, A., and Brew, A., 2014. Drawing is Thinking. *TRACEY: Drawing and Visualisation Research,* December 2014. Available at https://www.lboro.ac.uk/microsites/sota/tracey/journal/thin/2014/FKB-editorial.html.

Goldsmith, L., Simmons, S., Winner, E., Hetland, L., Hoyle, C., and Brooks, C., 2014. Geometric Reasoning and Drawing: Possible Interconnections Among STEM Subjects and Art. *TRACEY: Drawing and Visualisation Research,* December 2014. Available at https://www.lboro.ac.uk/microsites/sota/tracey/journal/thin/2014/PDF/Goldsmith_etal-TRACEY-Journal-STEAM-2014.pdf.

Ionascu, A., and Rohr, D., 2016. Drawing Now. *Drawing: Research, Theory, Practice* 1(1): 3-16.

Kalantzis, M., and Cole, B., 2012. *New Learning: Elements of a Science of Education*. Cambridge: Cambridge University Press.

Kelly, G., 1955. *The Psychology of Personal Constructs*. Vols. I and II. New York: Norton.

Kirsch, D., 2006. Explaining Artifact Evolution. In L. Malafournis and C. Renfrew (ed.), *Cognitive Life of Things: Recasting the Boundaries of the Mind*, Cambridge: McDonald Institute for Archaeological Research, pp. 121-144.

Kirsch, D., 2009. Interaction, Eternal Representations and Sense Making. In N. A. Taatgen and H. van Rijn (eds.), *Proceedings of the 31st Annual Conference of the Cognitive Science Society*, Austin, Texas: Cognitive Science Society, 2009, pp. 1103-1108.

Kirsch, D., 2014. Using Sketching: To Think, To Recognize, To Learn. *TRACEY: Drawing and Visualisation Research,* December 2014. Available at https://www.lboro.ac.uk/microsites/sota/tracey/journal/thin/2014/PDF/Kirsh-TRACEY-Journal-STEAM-2014.pdf.

Levi-Strauss, C.,1966. *The Savage Mind.* London: Weidenfeld and Nicholson.

Minsky, M., 1987. *The Society of Mind*. New York: Simon and Schuster.

Norman, E., 2015. Design Education Research: Its Context, Background and Approaches. In M. Tovey (ed.), *Design Pedagogy: Developments in Art and Design Education*, Oxford: Routledge, 2015, pp. 17-36.

Papert, S., 1982. *Mindstorms: Children, Computers and Powerful Ideas*. Jackson: Perseus Books.

Papert, S., 2005. You Can't Think About Thinking Without Thinking About Thinking About Something. *Contemporary Issues in Technology and Teacher Education* 5(3): 366-367.

Papert, S., and Harel, I., 1991. *Constructionism*. Norwood, NJ: Ablex Publishing.

Resnick, M., 1994. *Turtles, Termites and Traffic Jams: Explorations in Massively Parallel Microworlds*. Cambridge, MA: MIT Press.

Pessoa, F., 2007. *The Collected Poems of Alberto Caeiro*. Translated by Chris Daniels. Exeter: Shearsman.

Roworth-Stokes, S., and Ball, T., 2015. The Use of Design Case Studies in Design Education. In M. Tovey (ed.), *Design Pedagogy: Developments in Art and Design Education*, Oxford: Routledge, 2015, pp. 181-214.

Schiff, B., 2012. The Function of Narrative: Toward a Narrative Psychology of Meaning. *Narrative Works: Issues, Investigations, and Interventions* 2(1): 33-47. Available at https://journals.lib.unb.ca/index.php/NW/article/viewFile/19497/21063.

Tovey, M. (ed.), 2015. *Design Pedagogy: Developments in Art and Design Education*. Oxford, Routledge.Turkle, S., 2007. *Evocative Objects: Things We Think With*. London: MIT Press.

Turkle, S., 2011. *Falling for Science: Objects in Mind*. London: MIT Press.

Turkle, S., and Papert, S., 1990. Epistemological Pluralism and the Revaluation of the Concrete. *Signs: Journal of Women in Culture and Society* 16(1): 128-157.

Wentworth, P., Elkner, J., Downey, A., and Meyers, C., 2018. *How to Think Like a Computer Scientist*. E-book. Available at https://media.readthedocs.org/pdf/howtothink/latest/howtothink.pdf.

Wilde, J., and Wilde, R., 1991. *Visual Literacy*. New York: Watson-Guptil.

Wilensky, U., and Papert, S., 2010. Restructurations: Reformulating Knowledge Disciplines through New Representational Forms. In J. Clayson and I. Kalaš (eds.), *Proceedings of the Constructionism Conference 2010*, Paris. Available at http://ccl.northwestern.edu/2010/wilensky_restructurations_Constructionism%202010-latest.pdf.

ARTEFAKTAI, VIZUALINIS MODELIAVIMAS IR KONSTRUKCIONIZMAS: ŽVELGTI ATIDŽIAU IR STEBĖTI, KAS VYKSTA

James E. Clayson

Konstrukcionistai įveiklina galingą koncepciją, kuria jie dalijasi su konstruktyvistais: individualų mokymąsi sustiprina konkrečių idėjų, koncepcijų, metodų, objektų, aplinkos, jausmų, sapnų, prisiminimų ir garsų modelių kūrimas, pasitelkiant besimokančiojo žinias. Konstrukcionistai to siekia kurdami modelius ar artefaktus, kuriais jų kūrėjas gali išoriškai manipuliuoti, juos tyrinėti bei žodžiu dalytis su kitais. Konstrukcionistai mano, kad tokių diskusijų metu sukuriamos naujos žinios. Konstrukcionizmas turi daug euristinių metodų, kuriais galima atrasti ar konstruoti artefaktus ir šiuos artefaktus privačiai ar viešai aptarinėti. Konstrukcionistai teigia, kad tiek konstravimas, tiek aptarimas yra būtini giluminei prasmėkūrai.

Šiame straipsnyje aprašomas vienas konkretus konstrukcionistinis mokymosi metodas – vizualinis modeliavimas. Juo iliustruojama vieno pedagogo prieiga, sukurta per 40 metų pedagoginio darbo. Straipsnyje remiamasi atitinkama literatūra, aprašoma pedagoginė prieiga, ištekliai ir rezultatai, taip pat kaip pavyzdys smulkiau atskleidžiamas vieno studento mąstymo procesas. Galiausiai, tinkama naratyvine forma pateikiama 15 argumentų, kodėl vizualinis komponentas praplečia konstrukcionizmo projektą ir turėtų būti integruotas į daugiau švietimo programų.

Pagrindiniai žodžiai: konstrukcionizmas, vizualinis modeliavimas, transformuojami objektai, artefaktai, piešimas, naratyvinė psichologija

Įteikta 2018 09 19
Priimta 2018 12 17