The Building Blocks of Imagination: The Effects of External Factors on Constructivist Learning

by Douglas Bushong

Boise State University

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Abstract

This paper begins by providing a brief overview of constructivism, and posits that the model of the universe we build depends, in part, on the way we visualize that model. Research has shown several factors, such as language, physical perception, and preconditioned comparisons, can influence how we visualize natural phenomena. This paper describes applicable research in these areas, and suggests that further research can help us to form a clearer understanding of the background mechanism that affect visualization, and thus affect the constructivist model.

Keywords: Constructivist learning theory, Boroditsky, language and thought, external factors on learning.

Introduction

Scientific experiments often begin in the minds of scientists, taking the form of thought experiments, if-then statements, and logical arguments. These exercises and visualizations help them to make hypotheses and predictions, which lead to physical experiments that test these predictions. Often the original experiment was a visualization that only one or a few people in the world had ever considered; it was a unique culmination of prior experiences, spatial reasoning, imagination, and language that led to the breakthrough.

When faced with questions about physical phenomena, we generally perform some sort of visualization (Kind, 2005). It has long been debated whether this visualization is based on images (pictoralism) or words (descriptionism), and the purpose of this paper is not to come down on one side or the other. Rather, this paper is intended to explore how certain pre-programmed characteristics, including social tools, motor skills, and language, can affect human thought processes from a constructivist view. It will begin with a basic overview of constructivism, explore research on the effects of these characteristics on thought, and will try to identify areas where educational technology can be used to control these effects.

How We Learn

This paper is written from the perspective of a constructivist seeking to understand the groundwork necessary for constructivist learning to occur.

Constructivism

Constructivism is a relatively modern learning theory that has gained a lot of ground in recent years (Petraglia, 1998). The general theory of constructivism is that the individual forms

meaning from experiences, and that the way we interpret information influences how we derive meaning (Ertmer, 1993). In our minds, we build a model of the universe, and that model is constantly challenged by our moment-to-moment experiences. As these experiences continue to shape our model, we produce knowledge (Fox, 2001). With each challenge, our model is either reinforced by the new information through a process called assimilation *or* is changed by the new information by a process called accommodation (Block, 1982). This reinforcement or reshaping of the model is involuntary; if the mind believes the new information is accurate, then it is forced to change the model.

Generally, when we speak about the "experiences" that influence our own constructivist model, we are referring to concrete events and thoughts that occur within the span of our lifetime. While other theories, such as activity theory and connectivism, provide possible explanations for how knowledge can exist outside of our personal experience, even they seem to refer to knowledge gained by specific, concrete events and activities. Generally, the knowledge of mankind is passed on from generation to generation, and as the knowledge changes, so too does the context in which future generations learn.

The Influence of External Factors on Learning

What if our ability to build a model of the world is also influenced by something more fundamental and concrete experiences, such as language or the size and shape of our bodies? If so, this could be an indicator that the constructivist view is adequate for explaining *how* learning occurs, but inadequate for explaining *the conditions* under which learning occurs.

The mental tools that we use to form our model of the universe evolve over time. The mental tools that learners develop are often extensions of the physical tools they use on a daily

basis. For example, the shift from Roman Numerals to Arabic lead to changes in the way we perform mental calculations, which later lead to changes in number theory (Gauvain, 1998).

As another example, many aspects of the English language were established before we learned to speak. The existence of "to be" verbs, the use of relative direction, and the arrangement of our writing from left to right are just a few. If these factors cause us to visualize or imagine events in a certain way, then they may augment or limit our ability to visualize the connections necessary to make new discoveries and form new models.

An analogy would be a computer programmer who knows a single programming language. The programming language was developed external to the programmer and, while it may evolve in small increments over time, it is fundamentally the same programming language that it's always been. The programmer thinks in that language, and certain functions or programs may be difficult for the programmer to visualize because they would be difficult to perform in that programmer's language. Another programmer using another language, however, may have no trouble visualizing those functions because his/her language is more geared toward performing them.

Research on Perceptions of Space and Time

Our ability to accurately imagine or visualize a phenomenon depends partly on our overall spatial reasoning. For this reason, any factors that can influence our understanding of time and space can affect our imagination.

Language Space, and Time

One question to consider is whether our language can affect our thought processes. Spatial metaphors have been used to represent time in many different tests. We tend to use

spatial terms or time based actions: set your clock forward, it was a long night, the class was short, etc. There are variations, however, in the way speakers represent time, and this could influence the way we visualize it.

In recent years, Dr. Lera Boroditsky has researched the effects of language on the mind that may provide useful insight into the underlying mechanics that may be required for constructivist modeling to occur. Across multiple studies, English speakers were compared against Hebrew, Mandarin, Indonesian, and Kuuk Thaayorre speakers.

English vs. Mandarin

Across several experiments comparing English and Mandarin speakers, tests were performed to see if Mandarin speakers – who read vertically and tend to use vertical terms for time – also visualized time vertically. One study used spatial priming questions, followed by questions about time (Boroditsky, 2001). Another test took a much simpler approach: it defined a point in space as a moment in time, and asked both English and Mandarin speakers to identify the point that would represent the moment "before" that moment (Boroditsky, Fuhrman, & McCormick, 2011).

In each study, the results show that Mandarin speakers used a vertical metaphor for time more often than English speakers. For example, if the tester pointed to a point in space and said "this is today. Where is yesterday," the Mandarin speakers were 8 times more likely than English speakers to point to a location above the original point. This wasn't necessarily an indicator that Mandarin speakers *always* visualized time vertically; it only showed that they were more predisposed to think of time vertically than English speakers.

English vs. Hebrew

In another study (Fuhrman & Boroditsky, 2010), the researchers sought to learn how the direction of a written language can affect the subjects' spatial representation of time. English and Hebrew speakers were selected for this test because of the directional arrangement of their writing; English speakers read from left to right, while Hebrew speakers read from right to left.

The researchers conducted two experiments for spatial arrangement of events. In the first experiment, subjects were given a set of cards showing a sequence of events, and asked to arrange them in order. The results showed that English speakers arranged the cards from left to right, while Hebrew speakers arranged them from right to left. For the second test, subjects used the same "point in space" approach used in the Mandarin test above. Once again, there was a significant response of left-to-right for English speakers, and right-to-left for Hebrew speakers.

In another experiment, subjects were shown an image of an event, followed by a second image of the event at a time before or after the event in the same location. For example, they might initially see a picture of a partially peeled orange. This may be followed by a completely peeled orange (later) or a whole, untouched orange (earlier). Subjects were then expected to identify the relationship of the second image to the first image by pressing one of two adjacent keys on a keyboard marked "earlier" and "later." For half of each language group, the key arrangement had "earlier" on the left side; for the other half, the "earlier" key was on the right side.

The test studied how quickly respondents would respond, based on the key arrangement. The results showed that English speakers made faster judgments when the earlier response button was to the left, while the Hebrew speakers made faster judgments when the earlier response button was on the right.

English vs. Kuuk Thaayorre

In the Kuuk Thaayorre language, relative directions (left or right) generally aren't used. Instead, they use cardinal directions (north, south, east, west) during everyday speech. So a Kuuk Thaayorre speaker would not say "the bucket to your left," but rather "the bucket on your north-northwest side." A soccer coach attempting to teach a Thaayorre player might say "Run east, pass to your teammate on the south, and then run west to get into position." Incidentally, this use of absolute direction makes it necessary for the Thaayorre people to constantly maintain an accurate sense of the cardinal directions.

In a test comparing Kuuk Thaayorre speakers to English speakers (Boroditsky & Gaby, 2006), subjects were asked to arrange cards that represented a sequence on a table. An example of such a sequence would be five pictures showing five stages of a flower blooming. The subjects were given no instructions other than to place the cards in order.

The study found that the English speakers tended to arrange the cards from left to right, but the Thaayorre subjects arranged them in different arrangements each time. Further analysis showed that the Thaayorre subjects consistently arranged the cards *from east to west*, regardless of their physical orientation.

English vs. Indonesian

In another study (Boroditsky, Ham, & Ramscar, 2002), Indonesian and English speakers speaker were presented with images of events occurring as part of a sequences. Indonesian verbs do not have modifiers for tense, as English words do; they do not change the verb to denote whether it took place in the past, present, or future. The researchers sought to determine how Indonesian speakers would classify before-during-after sequences, and to identify where they

would see similarities and differences between images. The study was broken down into four experiments.

The first experiment involved showing the subjects images of either two people performing the same action at the same point in time (e.g. two people about to kick a ball, or two people kicking the ball, etc) *or* two images of a single person at different stages of kicking the ball. They were tasked with rating how similar the images were on a scale of 1 to 9, with 1 being "not similar" and 9 being "very similar."

The results showed that English speakers rated the same tense, different person images as more similar, while the Indonesian speakers rated the same person, different test images as more similar. To the English speaker, the similarity was in the action, but to the Indonesian, it was in the individual shown in the image.

The second experiment used all native Indonesian speakers, a portion of which were bilingual. The bilingual speakers were given the instructions in Indonesian. The results of this study were similar for the Indonesian speakers receiving Indonesian instructions. However, the Indonesian speakers who also spoke English showed a pattern between the all Indonesian and all English speakers. This seemed to indicate that learning English may have changed their perception of the images.

Physical and Mental Movement

What if our spatial reasoning is not only affected by language, but also by our mental perceptions of ourselves relative to the thing being visualized? If it is, then factors like our size, gender, nourishment, economic status, etc., could impact how we visualize spatial phenomena.

Motor Imagery vs. Visual Imagery

In one study (Flusberg & Boroditsky, 2011), the question was asked whether objects that are physically more difficult to move are more difficult to move mentally as well. Subjects were given a set of objects of different weights, and were provided the opportunity to physically manipulate them. Then the subjects were tasked with mentally rotating the objects. Their responses were timed, and the study demonstrated that the subjects took more time to mentally rotate the objects that were also physically difficult to rotate. Their physical experience with the object affected their mental experience.

An interesting twist was then added to this experiment: subjects were given a second test, but this time they were explicitly told to visualize the object rotating itself (as opposed to visualizing themselves rotating the object). This time, when the subjects attempted to visualize the object rotating, the time difference was all but erased. By removing their self-perception from the imagery, they had developed a technology that eliminated the mental limitation imposed by the motor visualization.

Preconditioned comparisons

In addition to language and the relative strength of our bodies, research has shown that imagery can also be influenced by points of comparison presented prior to evaluating the problem.

In another test, subjects were given pairs of objects with similar qualities (e.g. a goat and a horse), and asked to compare them. Some were asked to identify similarities between them, and others were asked to identify differences. In the end, they were asked to rate the similarity between those objects and other similar objects. In each instance, *regardless of whether they*

were asked to identify similarities or differences, the act of comparing the two similar items made people perceive them as being more similar (Boroditsky, 2007).

A similar experiment within the same study was conducted with dissimilar objects, and the reverse was found to be true. That is, dissimilar objects appeared to be more dissimilar to those that made comparisons, especially to those that were looking for differences.

Discussion

In each study, the subject's ability and method of drawing connections between disparate pieces of information was manipulated by inherent factors external to the information in question. This research may give us insight into the conditions necessary for certain phenomena to be understood.

In each of these instances, the research demonstrated how seemingly benign influences, such as language and physical shape, can affect our predispositions to visualize spatial and temporal phenomena. The impact of these influences is difficult to determine at this time; further research is required.

The capacity for these outside factors to affect visualization has two implications.

1. It provides insight into how the framework for an individual's constructivist model of the universe can be shaped outside of the context of simple assimilation and accommodation. With further research, we can get a better understanding of constructivism and other learning theories. The strength of connections formed by the connectivist model, for example, could be affected by the same external influences.
2. It helps us to see where technologies may be developed to counter or amplify the effects of these external factors. In the motor imaging vs. visual imaging experiment, for

example, students were given a mental tool that all but eliminated the difficulty in manipulating the object.

Conclusion

Certainly there are limits to how strongly these effects can be on our thought process. There are many examples of mental organization that does not support the notion that language is a major factor in concept formation (Bloch, 1991). However, the research shown here serves to demonstrate how language can *influence* – without dominating – our mental models of the world.

This purpose of this paper is not to state how much these factors limit or augment our ability to visualize certain phenomena. Rather, it is intended to identify where the research has brought us, and to serve as a springboard for further research. For example, could Hawaiian speakers who give directions in terms of *makai* (“toward the sea”) and *mauka* (“toward the mountain”) have a better understanding of polar coordinates because their understanding of direction is built around a shore surrounding a centralized point? Could Kuuk Thaayorre have an easier or more difficult time learning concepts like Galilean invariance and relativity? Could multilingual scientists have a greater capacity for visualizing phenomena and building predictable models? Further study may provide insightful answers to these questions.

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