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Constructionism & Microworlds

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What is constructionism?

Seymour Papert launched the notion of *constructionism* in the mid-nineteen eighties. The central idea is that a powerful way for learners to build knowledge structures in their mind, is to build with external representations, to construct physical or virtual entities that can be reflected on, edited and shared:

> *Constructionism […] 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, whether it's a sand castle on the beach or a theory of the universe. (Papert & Harel, 1991, p.1.*)

Constructionism therefore seeks, unlike Piaget's *constructivism,* to inform a theory of pedagogy, by directly addressing the question of how best to help learners learn. By constrast, constructivism is a theory of how people learn, irrespective of the circumstances of that learning, or whether teaching is involved at all (for an introduction to constructivism, see for example, von Glasersfeld,1989). As Papert goes on to put it, "the *n*-word rather than the *v*-word, constructivism", is aimed at trying to theorise strategies that align the way people learn with the ways it makes sense to help them learn, especially through the design of suitable artefacts. The word “especially” is crucial here, as it focuses attention on design: on the design of constructionist environments and then to the notion of a *microworld,* which we discuss later.

A classical example of a constructionist environment is Logo, the computer programming language derived from the artificial intelligence language, LISP (Harvey, 1997). Logo was, and still is in its various recent incarnations, a fully-fledged programming language by which people – including young children – can and do program anything they can imagine. Logo included a very powerful property, the *turtle,* a programmable screen object or robot that could, in a straightforward way, be controlled through Logo. This opened up three distinct but closely related affordances for the learner.

First, the constructionist environment represents a compelling medium in which to explore and learn, much as one can master a foreign language by living in the appropriate country. Second, in the environment, the learner can adopt a construction-based approach to learning in which there is some ownership by learners of the construction process, and which, potentially at least, leads to their engagement, confidence and empowerment. Third, exploration through building enables the learner to encounter ‘powerful ideas’ or intellectual nuggets, while ostensibly constructing something else, say, geometrical shapes on the screen in the case of turtle geometry, Lego robots, or musical composition.

The idea of constructionism inevitably draws attention to the central role of the tools to be mobilised for building, and for expressing what is being built. Constructionist tools should to be expressive: they can be shaped by their users to construct new entities (geometric shapes, linguistic structures, artistic creations), in ways that emerge in activity. At the same time, tools like this constrain and shape what learners can do, think and learn. Noss & Hoyles, (1996), discuss this reciprocity between the ways learners shape the tools they use and the ways that the tools shape learning, manifested in what they term situated abstractions. (See also the debate around the notions of situated abstraction, instrumental genesis and orchestration in Hoyles, Noss, & Kent, P., 2004).

The three affordances of Logo above, allow us to generalise the idea of constructionism beyond the case of Logo and its descendants. As Logo has evolved, and as the ambient digital space around it has evolved alongside (Logo was invented 30 years before the web!), the theory of constructionism has acquired more form, inspiring designers to build yet more technologies that support its key objectives: Boxer (www.soe.berkeley.edu/boxer/ Scratch(http://scratch.mit.edu/),NetLogo(http://ccl.northwestern.edu/netlogo/), StarLogo(http://education.mit.edu/starlogo/),ToonTalk(http://www.toontalk.com/) and most recently Raspberry Pi, http://en.wikipedia.org/wiki/Raspberry_Pi. In addition, numerous more knowledge-focussed environments have entered the arena, such as the dynamic geometry systems in mathematics or *Impromptu* in music (Bamberger and Hernandez, 1999). Over the years, constructionism has also provided the framework for a fertile strand of research detailing trajectories of learning with the tools, which range widely over topics as different as knot theory, learning styles, and musical composition. Eisenberg (2003) has also added to this mix through his description of how a constructionist approach can lead to a rich blend of traditional and computational material.

The discussion above illustrates that, as Papert was at pains to point out, constructionism seeks to develop knowledge structures in the mind alongside physical or virtual structures external to the mind, and as such is as much a theory of epistemology as of pedagogy, (see Harel & Papert, 1991). Papert explains that the distinction between *instructionism* and *constructionism,* is also about epistemology and not merely about two ways of thinking about the transmission of knowledge. Rather, the distinction *"goes beyond the acquisition of knowledge to touch on the nature of knowledge and the nature of knowing"* (Papert. 1993). In other words, constructionism involves choosing or designing representations, engaging artefacts and suitably oriented pedagogies that together can bring about fundamental change in *how* to learn and, if successful, will ultimately change *what* is learned.

Perhaps the best explanation of this epistemological shift has been explored by Wilensky and Papert who argue that constructionism has:

> *"shifted the focus from the means to the object of learning… how the structure and properties of knowledge affect its learnability and the power that it affords to individuals and groups. (*Wilensky & Papert, 2010, p.1).

The name they give to this process, is *restructuration,*

> *… the encoding of the knowledge in a domain as a function of the representational infrastructure used to express the knowledge. A change from one structuration of a domain to another resulting from such a change in representational infrastructure we call a restructuration.* (pp.2-3)

The example they give is the shift (though not, of course, made for educational purposes) from Roman to Arabic numerals, Papert, (2006), a shift that made it possible for nearly everyone to calculate in ways that were hitherto obscure. And when we think about this example, it is possible to identify where the computer presence has shifted not only how knowledge is spread and developed, but the nature of knowledge itself, in scientific, social-scientific and humanities disciplines (see for example Resnick, 1995).

One of the persistent challenges of realising the constructionist vision, is the tension between aiming to teach specific content of, say, mathematics or music, and *at the same time* afford the learner the experience of constructing, making, doing and problem solving. These two aims are, of course, not antithetical, but neither is it obvious how to align them for pedagogical purposes. One solution that has evolved has been to design 'microworlds', insulated and accessible islands of activity in which nuggets of relevant knowledge are encountered in a natural way – or at least, in which the chance of meeting the nuggets is designed to be as high as possible.

From Constructionism to Microworlds

Hoyles (1993) describes the evolution of the *microworld* idea from its genesis in the AI community, in which it was used to describe a relatively simple and constrained domain where computational systems could solve problems, to a more broadly conceived environment that served as a concrete embodiment of a knowledge domain or structure. The structure comprises tools that are extensible (so tools and objects can be combined to build new ones), but also transparent so their workings are visible, and rich in different representations. Edwards (1998) contrasts this 'structural' view of a microworld with a 'functional' view, which prioritises its features as they become apparent in use, as learners explore, build and learn from feedback (see also Kafai, 2006 for further discussion of constructionism and microworlds).

This functional view points to the importance of the way that knowledge actually grows in the learner. As diSessa (2006) points out, traditional instruction fails to engage with how knowledge is actually built, piece by piece, and layer upon layer. There is a duality here: a successful microworld is both an epistemological and an emotional universe, a place where powerful (mathematical, or scientific, or artistic) ideas can be explored; but explored 'in safety', acting as an incubator both in the sense of fostering conceptual growth, and a place where it is safe to make mistakes and show ignorance. And, of course, centrally these days, a place where ideas can be effortlessly shared, remixed and improved (for an earlier discussion of these twin aspects of engaging through building and sharing, see Noss and Hoyles, 2006).

Thus the emotional component is more than incidental to the microworld idea: building and sharing things is not much use for learning if learners do not care about what they are building and sharing. Papert's famous example in the preface to his book, Mindstorms (Papert, 1980), tells a story that is not just about how much he learned about mathematics by playing with gears, but is about how he 'fell in love' with gears, an intimate and consuming knowledge that he used as a model for future learning of mathematics. While discussing drawing and painting, Clayson (2008) also brings to the fore this emotional core of constructionism: "Programming in a language like Logo … shows there is no right solution to seeing, only a process which has to be individual". Gargarian,(1993), takes up similar aesthetic and artistic themes, in relation to music and textile design.

But as well as an intellectual challenge for authentic engagement, there are issues that are fundamental to general goals of learning. Confrey and her colleagues put it -- in relation to mathematics -- thus:

> *The importance of tapping into youth culture should not be underestimated in motivating and sustaining student educational progress. This is especially true for subjects like science and mathematics, which carry considerable social capital yet are easy for students to dismiss as irrelevant, boring and hard in a world of digital images, animations, easy information retrieval and communication. We need engaging environments, in which the mathematics is actually needed for students to achieve goals that they find compelling, and made visible to students and expressed in a language with which they can connect. (*Confrey et al, 2010, p.20).

Outstanding challenges

In this concluding section, we point to some outstanding challenges to the constructionist/ microworld agenda from a theoretical point of view.

First, we need to pin down more precisely what kind of a thing constructionism is. While the constructionist project might seem like a theory, it is perhaps best thought of as not so much a theory, but as a principle or even a manifesto since, as Clayson (2008) remarks, it is “rich in interpretative potential and rich in its ambiguity“ p.142. Cobb and diSessa, (2004) make a similar point when they suggest that constructionism presents more a “framework for action” than a theory, providing “some focus and direction to the design of learning environments with much left implicit and open to diverse interpretation”, p.82. Nonetheless, they underline the point made earlier: that the idea of students’ learning through design is compelling since it combines affective and cognitive properties (see also diSessa, 1995 for elaboration of the relationship between epistemology and system design).

The second challenge is that although microworlds are intended to orient students towards a way of thinking carefully structured by the designer, learners must also gain some autonomy. This means, of course, that learning will not occur precisely as planned. Thus, an inevitable challenge arises: how to balance self-motivated activity while maximising the opportunity to encounter the planned powerful ideas (see the ‘Play Paradox’, Noss &

Hoyles, 1996). Indeed, some of the papers cited have, over time, treated this paradox as solved – but better, perhaps, to think of it as a paradox-in-resolution: the challenge of designing engaging, compelling, and intellectually powerful learning environments is one that will surely never be totally resolved (see the cluster on *self-regulated learning* in this volume).

The third challenge is to understand the extent to which ideas developed within a given medium 'transfer' (whatever that means) to knowledge independent of that medium? How does the knowledge gained within a microworld extend beyond the context of its genesis? (see Pratt & Noss, 2002. for a contribution on this theme).

The answer may necessitate looking beyond the notion of an individual constructing his or her own knowledge towards a consideration of the social framework within which activities take place and how social interaction transcends and transforms individual conceptual structures. It is these active encounters in which knowledge is co-constructed through experimentation and social engagement that might form the engine of transfer.

At the same time, the momentum of technological change will raise delicate challenges for constructionist design. As the opportunities for collaborative learning, seamless and flexible interaction and access to information increase, there is no guarantee that these will enhance learning. To take just one example: the 'App' culture is not necessarily supportive of the constructionist project, but App Inventor (http://appinventor.mit.edu/), which allows students to program *their own* Apps, could certainly point a way forward. The focus here is on the creation of engaging culturally resonant artefacts which simultaneously afford learners the opportunity to encounter powerful computational ideas.

Titles in red are the chosen four.

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