AIMS AND SCOPE

CONSTRUCTIVIST APPROACHES support the idea that mental structures such as cognition and perception are actively built by one’s mind rather than passively acquired. However, constructivist approaches vary in function of how much influence they attribute to constructed mental structures gradually adapting to the structures of the real world. Others seek to avoid this dualism. Either they skeptically reject that the structures of the real world can be compared with mental ones, or they embrace a phenomenological perspective that considers cognition as the grouping of experiential complexes. Some regard perceived regularities as invariants of inborn cognitive operators. Constructivist approaches can be said to differ also with respect to whether constructs are considered to populate the rational-linguistic, the biological-bodily, or the social realm.

SUBMISSIONS

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Constructivist Foundations publishes:
- scholarly papers dealing with the conceptual analysis of constructivist concepts;
- research papers covering experiments in constructivism;
- papers reporting on synthetic formal or computational models relevant for constructivist approaches;
- survey articles;
- editorial material such as opinions, perspectives, essays written by senior scholars, and open peer commentaries;
- book reviews.

Occasionally the journal publishes special issues on a specific topic. SUBMISSIONS ARE SUBJECT TO EDITORIAL AND DOUBLE-BLIND PEER-REVIEWING.

COMMON DENOMINATORS

The common denominators of constructivist approaches can be summarized as follows.
- Constructivist approaches question the Cartesian separation between “objective world” and subjective experience.
- They demand the inclusion of the observer in scientific explanations.
- No representationalism: knowledge is a system-related cognitive process rather than a mapping of an objective world onto subjective cognitive structures.
- According to constructivist approaches, it is futile to claim that knowledge approaches reality, reality is brought forth by the subject rather than passively received.
- Constructivist approaches entertain an agnostic relationship with reality, which is considered beyond our cognitive horizon, any reference to it should be refrained from.
- Therefore, the focus of research moves from the world that consists of matter to the world that consists of what matters.
- Constructivist approaches focus on self-referential and organizationally closed systems; such systems strive for control over their inputs rather than their outputs.
- With regard to scientific explanations, constructivist approaches favor a process-oriented approach rather than a substance-based perspective, e.g., living systems are defined by processes whereby they constitute and maintain their own organization.
- Constructivist approaches emphasize the “individual as personal scientist” approach, sociality is defined as adapting within the framework of social interaction.
- Finally, they ask for a less dogmatic approach to science in order to generate the flexibility that is needed to cope with today’s scientific frontier.

PUBLISHER

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Center Leo Apostel for Interdisciplinary Research
Vrije Universiteit Brussel
Krijgskundestraat 33
1160 Brussels, Belgium
http://www.univie.ac.at/constructivism/journal
http://www.constructivistfoundations.info
ISSN 1782-348X
PHYSICAL WEB SERVER
University of Vienna, Austria
GRAPHICAL CONCEPT
aspectdesign, Brussels, http://www.aspectdesign.be

COVER ART OF CURRENT ISSUE

«Blanks»
© by Daniel D’Aquila, 2012
acrylic paints on 18x24” canvas
courtesy of the artist
T his special issue was inspired by the conference and productions of the “Constructionism 2014” conference in Vienna, “Constructionism and Creativity.” The conference was the third in a row, after Paris in 2010 and Athens in 2012. It originated from a long-standing conference that had run for 30 years, “Eurologo,” after intense reflections. These lead to its restructuring to focus on the essence of understanding and designing for educational practices involving the construction of meanings individually and in social settings where bricolage with expressive digital media has a primary role.

Constructionism was the term coined by Seymour Papert (Papert 1987; Harel & Papert 1991) to draw our attention to the meanings learners generate while they engage in bricolage with expressive digital media (Papert 1972, 1980). Implicitly, constructionists have perceived meaning making through the process of tinkering with digital media as a creative activity (Kafai, Peppler & Chapmain 2010; Resnick, Berg & Eisenberg 2000). However, little explicit attention has been given to the kinds of creativity inherent in constructionist activity as such (Liljedahl & Sriraman 2006). Researchers on creativity in learning have recently moved on from perceiving it as a gift (Mann 2006) to adopting a wider view that meaning making is creative in itself (Sternberg & Lubart 2000).

Papert challenged contemporary readings of Piaget that to study learning was mainly about describing learners’ shortcomings in understanding taken-as-ontological meanings at different stages in life. Instead, he pointed to Piaget’s constructivist ideas, focusing specifically on the potential for the uses of digital media in pedagogy and in domain knowledge, albeit for mathematical learning processes. Constructionism endorses the principles of radical constructivism, i.e.,

**1. Knowledge is not passively received either through the senses or by way of communication, but is actively built up by the cognizing subject. 2. The function of cognition is adaptive and serves the subject’s organization of the experiential world, not the discovery of an objective ontological reality.** (Glaserfeld 1988: 85; quoted in Riegler & Steffe 2014)

However, it organically includes the uses of digital media as one of the means of externalizing meaning by expressing thoughts and meaning along with language, gesture and other representational registers (Morgan & Kynigos 2014). Meaning is thus communicated amongst individuals and made more visible to researchers by means of changes made to the artifacts in question (Weir 1986).

Papert claimed that digital artifacts could play the role of expressive media, augmenting opportunities for meaning making in pedagogically engineered learning environments. In that sense, constructionism began drawing attention as an epistemology of mathematical learning and as a design theory and perhaps less attention to a third aspect, that of a theory of learning (Kynigos 2015). The two former aspects were confrontational yet stimulating and visionary in their time.

With respect to epistemology, constructionism had extended to young children Imre Lakatos’s provocative portrayal of the process of mathematicians doing mathematics as the production of potential axioms and proofs in order to engage in the process of refuting them (Lakatos 1976). Lakatos’s claim was that mathematicians express mathematical ideas in order for them to be refuted by themselves or by others. The essence of the mathematical process is a reciprocity between proof and refutation. Perceiving mathematics as the set of end products of this process does not give an accurate idea of what it means to engage in mathematical activity. Papert’s suggestion was that students could use the computer to construct models of figures by means of programming (Papert 1972). He refined his theoretical claims by developing and using the Logo programming language and in particular “Turtle Geometry,” where programs create figural models made by changes to the “turtle’s” state (the turtle was a model of a vector with position, heading and zero length, see Abelson & diSessa 1981). These models, both their figural and formal descriptions, were seen as externalized expressions of ideas and thoughts. The act of constructing a model constituted making a sequence of ideas public for discussion and change. The models or artifacts thus had the status of being malleable, of being questionable or improvable propositions for an on-going discussion around subsequent changes to the artifacts. They had the same role as Lakatos’s mathematical propositions expressed by mathematicians with formal notation in order for a refutation-and-proof dialectic process to start. Only here, the representations, albeit mathematical, were connected and designed for youngsters to use and give meaning to; the expressive tool used provided feedback, and interactivity and the constructions were extensible (Papert 1980). The same applied with respect to programming, where Papert made the
same analogy between the activity of professional programmers working with the LISP language (Sinclair & Moon 1991) and young learners.

With respect to design, Papert was also the first to suggest that designing environments for rich meaning making was possible. He coined the notion of a "microworld" to describe a digital artifact designed to invite engagement in activity, ownership of ideas and learning style and exposure – i.e., expressing one's own ideas to others – for exploration, negotiation and communication (Healy & Kynigos 2010). Microworlds are self-contained worlds where students can "learn to transfer habits of exploration from their personal lives to the formal domain of scientific construction" (Papert 1980: 177). Later elaborations of the term referred to tasks for the learner that invited meaning making, to the embedding of powerful ideas in a microworld (Sarama & Clements 2002) and to the pedagogical technique of designing fallible artifacts, termed "half-baked" microworlds (Kynigos 2007). "Half-baked" microworlds are intentionally incomplete or buggy models given to learners to try out, to open up, to make changes to and to re-mix. They are like re-futable mathematical propositions, artifacts to generate meaning-making environments with considerable focus and structure. The art in designing a half-baked microworld is thus to think of what mathematics to take away from a generalized model. Designing these kinds of artifacts was also important in changing the perception that concrete thinking was a "lesser" kind of cognitive process than abstract thinking by pointing out that proper and rich exposure to the former was pivotal in ever hoping to reach the latter (Turkle & Papert 1991). Work on design has also pointed to the need to reconsider the ways in which domain knowledge is structured in education with a view to shape structures so that they become more amenable to meaning making by changing representational registers, engineering situations where meanings become useful and usable and inventing affordances for bricolage and construction of models (Wilenssky & Papert 2010).

Some work has been done to develop scientific validation of learning processes in constructionist environments. One such tool, used to understand meaning-making processes while learners work with a microworld, distinguishes between discriminat-
ing, using, generalizing and synthesizing mathematical ideas (Hoyles & Noss 1987). Another points to engaging in abstractions within situations where students use particular representations and affordances to generate particular digital constructs (Noss & Hoyles 1996). However, not unlike discourse amongst constructivist theorists (Riegler & Steffe 2014), constructionist theory does not only address the individual (Resnick 1996). Yasmin Kafai and Quinn Burke (2014) elaborated on the process of constructionist activity in interactionist and more broadly social settings. They studied meaning making during students' exchange, re-mix and publicizing of their artifacts and their engagement in discussion, discourse, dialogue and negotiations over the process of bricolage.

This special issue reflects the discussions on constructionism as epistemology and as a usefully developing theoretical tool for designing for and understanding – as Richard Noss and Jim Cl ayson put it in their opening article – "behavior and expression" with digital artifacts. The authors of the opening article discuss an agenda for constructionism based on the need to emphasize and enhance its scientific validity as a theoretical tool for understanding and designing for learning with expressive digital media from a constructivist perspective. Their agenda points to pivotal aspects of learning with digital media, such as modeling and learner accessibility to the modeling process, representing knowledge in a learnable language and making it possible for learners to decide how deep to dig into ideas embedded into the tools, their behaviors and functions. Furthermore, they stress the importance of tapping into youth culture, democratizing design by recognizing its value for learning and better understanding the ways in which digital artifacts are mediated within communities through a reciprocal shaping process.

The target articles in the issue not only reflect the various aspects of Noss & Clayson's agenda but raise broader issues involving particular ways in which constructionism addresses issues pertinent to the constructivist discourse.

With respect to the agenda, Nicole Panorouk & Alan Maloney and Eirini Geraniou & Manolis Mavrikis address domain knowledge and the question of what is learned by considering particular concepts during geometrical transformations and algebraic abstraction. The former authors discuss interesting ways in which 4th graders reasoned about translations and rotations with a specially designed tool involving figural representations and transformation animations. The latter studied 11–14-year-olds' work with a tool for representing algebraic generalizations of tile pattern descriptions, and studied the ways in which the students were supported to express algebraic meaning while transferring from digital to pencil and paper notation.

But there is also a need to understand constructionist learning processes better, as exemplified in the article on the process of deconstructionism by Pavel Boychev, and on the process of pattern identification to understand early algebraic concepts through modeling by Chrystalla Papademtri-Kachrimani. Boychev worked with university undergraduates and secondary students learning to program and particularly focused on the creativity and the meanings generated during the process of deconstructing digital models, claiming that deconstruction has been given little attention although it is a mirror activity to construction. Papademtri-Kachrimani shows how researchers, teachers and 5-year-old children creatively learn how to think about and connect patterns to numerical relations with a modeling kit made up of tangible rings.

Maria Daskolia, Chronis Kynigos & Katerina Makri discuss how to elaborate and re-consider the role of "powerful ideas" embedded in digital artifacts and the ways in which they can be utilized in broader educational contexts where the target is a loosely-defined complex system such as the issue of city sustainability, rather than a conceptually cohesive microworld. Their article raises questions such as: Does constructionist learning only need to be about working with models? Or only about scientific/computational models? Can a piece of art, a piece of text, a human situation game usefully play the role of a constructionist artifact? Chronis Kynigos discusses how to think of the role of emerging new kinds of...
artifacts, such as constructionist e-books, as expressive media and of the processes by which they are mediated in communities. Edith Ackermann raises the issue of going beyond the cognitive and social aspects of meaning generation by seriously considering the affective, and in particular, humor. She takes three examples, the craftsman, the poet and the trickster, to show some of the oblique ways of knowing, such as “possibilizing” that bring insight and creativity.

The importance of developing methods and tools to understand the social and systemic contexts within which constructionist activity may take place is discussed, for instance, by Karen Brennan involving classroom practices and by Kynigos involving design communities. Brennan discusses ways in which teachers can be supported to support constructionist learning in the classroom in turn by placing teachers in the context of designer communities that discuss the artifacts they create and their agendas for how to use them with their students. The importance of the endeavor to address the broader education community by joining in wider discourses permeates some of the papers, see, e.g., Kynigos, Daskolla et al. and Ackermann. Respectively, they discuss constructionism in designing and “reading” e-books, constructionism in broader challenges to meet complex loosely-defined tasks where powerful ideas only play secondary roles and meaning making is a process not only involving the cognitive and the social but also affect and humor.

This issue thus attempts to situate constructionism within the constructivist discourse and then beyond that within the wider educational discourse to elaborate on its identity, connectivity and coherence, joining in the process of networking amongst theories (Prediger, Bikner-Ahsbahs & Arzarello 2008; Kynigos 2012). It also attempts to draw attention to the role of digital artifacts in expression, representation and meaning making individually and in social contexts. Much like constructionist theory so far, creativity is implicitly inherent in papers in the issue, especially those more narrowly connected to domain knowledge, such as those of Panorkou & Maloney, Papademetri-Kachrimani and Geraniou & Mavrikis. Some others, however, bring the issue of creativity up front, showing how social creativity in learners (Daskolla et al., Ackermann, Boychev) and resource designers and teachers (Kynigos, Brennan) can be seen as an explicit aspect of meaning making in social constructionist settings.

There is more to be done on all three aspects of constructionism, i.e., epistemology, design and learning theory. The education world is in flux: knowledge domains, their structure in educational settings and the fragmented nature in which they are placed in curricula are all being questioned in the emergent knowledge society. Papert’s visionary and provocative challenge to question how we view learning and knowledge from an epistemological perspective is even more relevant some 40 years later. The democratization and recognition of designing artifacts, activities and resources as a natural aspect of professional activity for teachers and others in the education field is drawing attention. The need to develop theoretical tools for understanding the design process from the professional’s point of view and its potential relations to affording constructionist learning styles is becoming clearer. Finally, Noss and Clayson cite Andrea diSessa and Paul Cobb to stress the need for the production of more fine-tuned systematic theory for constructionist learning, i.e., to “develop theoretical constructs that empower us to see order, pattern and regularity in respective educational settings” (diSessa & Cobb 2004: 84).
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It is now a quarter of a century since the idea of constructionism was launched by Seymour Papert – the n-word rather than the v-word, constructivism (Papert & Harel 1991: 1). While the latter idea captured nicely the psychological substrate on which all learning (irrespective of teaching) is built, the n-word sought to develop a theory of pedagogy that could foster learning. More than that, while the constructionist project seems like a pedagogical theory, it is as much a theory of epistemology as one of pedagogy: understanding the development of the structure of knowledge is part of and integral to the encouragement of an inclusive and powerful pedagogic theory and practice.

Constructionism symbolised a way of thinking about learning, a metaphor for the ways that human beings come to learn most effectively: building a model, reflecting on it, debugging and sharing. All this was to be achieved in ways that were “reasonably straightforward” thanks to digital technologies – in particular what Seymour called its “Protean” nature, i.e., its potential to present itself with any number of faces. The Logo programming language (Papert 1980) was emblematic of this approach and has left its mark on the educational world, which has already shown signs of contributing to the creation of those environments can be made more effective.

Another reason for constructionism's slow burn is that constructionism is often confused with its psychological cousin, constructivism – a word that has all but lost its actual meaning in the rush to embrace an alternative to behaviourism and its offshoots; a meaning diluted to the point that almost any pedagogy is routinely described as “constructivist,” as if a recognition of how humans learn is sufficient for prescribing how and what they should and could be taught.

But perhaps the fundamental difficulty of constructionism as an organising framework is simply that it is, at core, an epistemological idea, and one that has been insufficiently theorised by researchers and practitioners. There is an extreme reluctance in the educational enterprise to discuss what to teach in the light of new tools and new goals for the curriculum, a reluctance whose inertia pales into insignificance in the face of a simple evolution of pedagogic approach. Compared with re-evaluating what can be taught and to whom, the switch from instructionalism to some other ism that recognises the complexity and heterogeneity of learners is far from unproblematic.

The problem is that if conceived merely as a pedagogic strategy, constructionism does not offer in concrete terms much more than a host of other worthy slogans such as “discovery learning,” “exploratory learning” or “enquiry based” learning.

Of course, even if there were to be a widespread wish to change what to teach, in the interests of engagement and accessibility for example, we should not underestimate how hard the endeavour is. Where does one start and how does one progress when every design decision has enormous consequences for possible actions, the language in which the actions are expressed in a model, the language through which the actions are shared, the planned sequence of work, etc. All of the above can only be undertaken in an iterative spiral of “design-and-test” among an interdisciplinary team of educationists, computer scientists and teachers.

**What kind of a theory is constructionism?**

Our starting point is a seminal paper by Andy diSessa and Paul Cobb (2004). In it, they argue for the importance of theory in educational design experiments, and they survey different roles played by theory in design. They differentiate between four types of theory – from “grand” theories such as Jean Piaget’s constructivism (which they properly point out was not intended to and largely fails to inform design) to “domain specific instructional theories,” which involve testable conjectures about learning processes and how to devise pedagogic situations that foster them.

**Constructionism**

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> Upshot: Constructionism must return to its epistemological roots to make any lasting impact on education. Constructionism should be transformed from a framework of action into ways to conceptualize and record what people actually do in constructionist environments so that theories of knowledge-building acts can be tested and the designing of those environments can be made more effective.

http://www.univie.ac.at/constructivism/journal/10/3/285.noss
DiSessa and Cobb suggest that constructionism, like “learning by designing” falls into a category they call “Frameworks for Action,” and they argue that while these frameworks do provide some heuristic power and structure to the design of learning environments, they typically…”

“...do not cleanly separate their scientific claims and validation from their suggested actions. That is, the theory or theories behind frameworks for action are relatively inexplicit, complex, and often involve multiple very diverse elements that cannot plausibly be brought under a single umbrella.” (DiSessa and Cobb 2004: 82)

DiSessa and Cobb argue for the need to “manage the gap”; the failure of most frameworks to accommodate the complexity and interactions between the elements of instruction. It is trivial to note that instructional effectiveness depends on many variables, not least the nature of technology, a field that is chaotic in the literal sense: tiny changes in, for example, the user interface can make massive changes in learning. The primary point is that in order to “test” theory, it is necessary to maintain a gap between the pedagogical strategies at stake and the theories that motivate them: one cannot prejudge what is to be found when attempting to “apply theory to practice.”

The point is that in designing learning environments that integrate digital technologies, one needs to recognise that the tools made available shape the activity in ways that to some extent are predictable but in some are not. In addition to considering the specific affordances and constraints of different digital technologies for structuring learning experiences (including various software packages, hardware configurations and the Internet), there are also implications of design decisions on tools, curriculum, teaching and learning and, of course, assessment — all huge issues in education.

DiSessa and Cobb claim that it is necessary to “develop theoretical constructs that empower us to see order, pattern, and regularity” in the settings under investigation. Their research argues that students’ construction can be studied under proper conditions. However, designing those conditions in a variety of different disciplines — not just mathematics and science — is the crux of the difficulty confronting constructionism as a theory.

The prevalent assumption underpinning most educational research — and by implication the producers and consumers of education research — is that the fundamental concepts remain invariant over time and technologies. It is tempting to take this observation as merely trivial: educational change is slow, it seldom takes account of the possibilities of knowledge transformation, and it is almost always concerned only with teaching more effectively, rather than learning within new epistemologies.

While this is correct, it misses a key point about constructionism. When we build, we build with things — not just ideas. Of course, if we design properly, the things we build with have an epistemic foundation — of “powerful ideas,” say, that students are supposed to bump into, or perhaps we should say, create. But the ways the things are connected in construction, the relationships between them, and the behaviours they are given have to be expressed in the system of the things, not in the system of ideas. We could express the fact that the paragraph settings of this paragraph are contained in the final paragraph marker as a one or two of code; but as we are building this paragraph, it is much more natural to say (to ourselves), “If we merge this paragraph with this one, it will inherit the second one’s properties. Note the informal nature of our expression: ‘this’ means nothing outside the situation of writing.”

This particular property of construction systems (such as programming languages) is both a powerful advantage and a difficulty. It is powerful because the complexity of an idea often inheres in the way it is represented, but that representation is not just in the program code. The act of programming encourages a form of layered model building of text, diagrams, group narratives and sketches that surround and embellish the code. We use these tools/objects/words/phrases to speak freshly. In a way, we build a new language of specific objects by using a specific source language. How to extend that new vision into other specifics is tricky.

Let us give an example of this problem. Over many years we noticed a recurrent pattern in students building computational expression for mathematical and scientific ideas. We saw that while they seemed often clearly able to abstract from the particularities of the activity, as evidenced by an often implicit recognition of the relationships between variables, these abstractions did not resemble in their expression the standard forms of algebraic or even quasi-algebraic representations. Naturally enough, they employed the tools — objects and relationship between objects — that they had used successfully in the activities. The tools-in-situation, in other words, acted as a means to express abstractions that might not have been expressible in standard forms: we called these “situated abstractions” (Noss & Hoyles 1996) to try to capture this idea.

Situated abstraction identifies and organises a class of behaviour and expression that occurs in the context of activity in constructionist environments. Like any useful theoretical idea, its power lies in its application — in the potential of the idea that started as an observation of behaviour to influence and shape behaviour.

This is a major challenge of research: to transform constructionism from a framework for action into a set of ways of conceptualising what people do in constructionist environments that can simultaneously assist in designing those environments. We attempt to take a step in this direction, by seeking to make explicit what we see as the defining characteristics of a constructionist agenda, which together define its distinctive character.

Characteristics of a constructionist agenda

Central to any notion of constructionism, and its first defining characteristic, must of course be the idea of modelling: that is, by creating external building blocks by a process of building, reflecting and debugging, learners can develop relevant internal knowledge structures. Modelling, approached in this way, promotes the learning of powerful ideas through use, in contrast to the conventional way of much teaching (Papert’s 1996 “Power Principle”). A key rationale for modelling (at least in the context of mathematics) involves using and discriminating crucial invariants, generalising and
synthesising, within a framework of iterative design, a necessary condition if learners are to develop agency over the evolving knowledge. Thus modelling emphasises the utility of a mathematical concept from the learner’s perspective. Jere Confrey and Alan Maloney describe this process in a similar vein:

“(T)he modeling produces an outcome – a model – which is a description or a representation of the situation, drawn from the mathematical disciplines, in relation to the person’s experience, which itself has changed through the modelling process.” (Confrey & Maloney 2007: 60)

Students live in a world increasingly permeated by technology – the internet, satellite communications and mobile phones. Their lives are managed by numerous technological systems, many of which are largely invisible (transportation, finance and loans, manufacturing, demographics, medicine, and so on; see, for example, Hoyles et al. 2010). So, a second characteristic of the constructionist agenda should embrace the issue of accessibility to the modelling process: learners develop an awareness of the existence of models and how they shape actions; then they are provided with a glimpse of how this happens.

Our approach to this challenge has been through layering of mathematical and scientific principles and abstraction, and thus embedding increasing problem-solving complexity into the software. This again affords a higher degree of user agency: learners can decide how deep they dig into the “why” of the software feedback, or if they want to be able to edit or extend the models. The idea of layering is a third component of the constructionist agenda.

A fourth characteristic is tapping into youth culture, or more generally, seriously seeking to engage with learners’ agendas. This effort should not be underestimated and is especially important for subjects such as 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, instant information and communication. We have tried over many years to design and build engaging environments, in which the knowledge (say, some mathematical content) is actually needed for students to achieve the goals of learning.

This brings us to the fifth characteristic: that the knowledge is made visible by being represented in a language with which learners can express themselves. Just what “language” means in this context is crucial, and we will not explore this complex issue further here.

The sixth characteristic moves the focus of attention in the constructionist agenda more towards appropriate pedagogy: effective student learning is promoted through long-term engagement in collaborative projects during which students take individual and collective responsibility (e.g., Harel & Papert 1991) and there is sustained emphasis on content knowledge. This last characteristic points to collaboration, which is worthy of a separate defining characteristic of a constructionist agenda, not least as we are seeing rapid developments in the ways that it is possible for students to share resources and ideas and to collaborate through technologi-

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is Professor Emeritus at the American University of Paris (AUP) where he taught applied mathematics and visual thinking for thirty years. He specialized in designing computational environments where liberal arts undergraduates could explore the power of building personal models that link the visual, the qualitative and the quantitative. He won AUP’s outstanding teacher award three times. His early book, Visual Modeling with Logo: a structured approach to seeing (1988), was published by MIT Press in its series of constructionist explorations using the Logo language. His latest book, A Computational Eye, (in process) uses the Python computer language and was tested on students at Deep Springs College (California) where he was a visiting professor in 2015. Jim was educated at MIT, the University of Chicago and the School of Oriental and African Studies (University of London).
cal devices, both in the same physical space and at a distance.

Most of the above criteria imply considerable investment in design, a crucial dimension in the educational use of technology, but one whose difficulty tends to be seriously underestimated. Particularly in the case of widely used educational tools, decisions taken by a small number of designers shape the way educators have to think about teaching and learning with technology. Most digital technologies do not make explicit how they work or how they could be used in education. This means that taking account of their design, particularly in terms of implications for epistemology, is a central challenge. But, as we attempt to incorporate new technological tools into teaching and learning, we must seek to make progress in trying to understand how the related epistemological structures are mediated by learning communities, and reciprocally, how learning communities are shaped by the artefacts and technologies in use. Bringing in tools to foster collaboration brings more complexity to the issue of design, since again the technical aspects shape what students can do with the technology, what they can share and how they can interact.

This means that we are designing for a moving target in all these directions: a challenge for designers, researchers, learners and teachers. Yet the implications for learning and teaching are beginning to be explored and appropriate theoretical frameworks put in place.

**Note**

An earlier version of this paper was given at Constructionism 2010, Paris, France.

**References**


Received: 3 July 2015
Accepted: 8 July 2015
Constructionism

Beyond Technocentrism
Supporting Constructionism in the Classroom

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> Context • In 2015, we are surrounded by tools and technologies for creating and making, thinking and learning. But classroom “learning” is often focused on learning about the tool/technology itself, rather than learning with or through the technology. > Problem • A constructionist theory of learning offers useful ways for thinking about how technology can be included in the service of learning in K–12 classrooms. To support constructionism in the classroom, we need to focus on supporting teachers, who necessarily serve as the agents of classroom-level innovations. This article explores a central question: How can we support teachers to engage with constructionism as a way to think beyond a technocentric view in the classroom? > Method • I approach this work from the perspective of a designer, using the process of supporting teachers working with the Scratch programming language in K–12 classrooms as a central example. I draw on reflections from six years of the ScratchEd project, which includes interviews with 30 teachers, and observations from teacher professional development events and an online community of educators. > Results • I describe five sets of tensions that I encountered while designing the ScratchEd model of professional development: tensions between (1) tool and learning, (2) direction and discovery, (3) individual and group, (4) expert and novice, and (5) actual and aspirational. I describe how these tensions are negotiated within the elements of the PD model (an online community, participatory meetups, and an online workshop). > Implications • The tensions I describe are not specific to Scratch, and can serve as a more general model for PD designers to scrutinize and critique. > Constructivist content • This work contributes to ongoing conversations and questions about how to support constructivist/constructionist approaches in classrooms. > Key words • Constructionism, technocentrism, teachers, professional development, ScratchEd.

Technocentrism

« 1 » In the mid-1980s, Seymour Papert wrote a position paper entitled Computer Criticism vs. Technocentric Thinking. A principal argument of the paper was that conversations about technology and learning too often begin and end with the technology itself, without acknowledging the complexity of the environment in which the technology is situated. Papert described this technology-limited view as technocentrism.

Technocentrism refers to the tendency to give [...] centrality to a technical object – for example computers or Logo. This tendency shows up in questions like “What is the effect of the computer on cognitive development?” or “Does Logo work?” Of course such questions might be used innocently as shorthand for more complex assertions, so the diagnosis of technocentrism must be confirmed by careful examination of the arguments in which they are embedded. However, such turns of phrase often betray a tendency to think of ‘computers’ and of ‘Logo’ as agents that act directly on thinking and learning; they betray a tendency to reduce what are really the most important components of educational situations – people and cultures – to a secondary, facilitating role.” (Papert 1987: 23)

« 2 » Thirty years later, very little has changed. In 2015, we are surrounded by tools and technologies for creating and making, thinking and learning. But when learners encounter this wide range of technologies in the classroom, their experiences are still too often centered on technology itself (Buckingham 2007; Cuban 2001; Kimmons 2015; Seewyn 2011; Seewyn 2014). The “learning” is focused on learning about the tool/technology or the effects of the tool/technology itself, rather than learning with or through the technology. The questions that are asked about impacts and outcomes strive to isolate the technology as the source of change. We still seem hopelessly stuck in a technocentric view.

« 3 » How, then, can we defend against technocentrism in the K–12 classroom? Taking an extreme approach, we could exclude digital and network technologies from core classroom experiences, reducing their role to that of peripheral luxuries, to be indulged only occasionally. Although this approach may appeal to some, it is fundamentally untenable. Technology is an important part of our world and young learners are better served by gaining fluency with technology than by avoiding it. And beyond arguments about the centrality and significance of technology in modern life, technology can also play an important role in supporting learning processes (Collins & Halverson 2009; de Jong & Pieters 2006: 740). Digital and network technologies can serve as powerful mediums for communicating understanding, connecting learners, and constructing knowledge.

« 4 » Rather than uncritically embracing or rejecting technology, we should consider how best to include technology in the service of classroom learning. Part of this work is technocentric – basic understanding of technology is a necessary precondition.
for learning with and through technology. But while a focus on technology itself may be a starting point, this approach will not, by itself, result in a more transformative trajectory of use (Liff & Shepard 2004). To achieve this, technology needs to be accompanied by a clear theory of learning, guiding the use of technology in the service of learning (La-joie & Azevedo 2006: 803).

"5 In this article, I argue that a constructionist theory of learning offers useful ways for thinking about how technology can be included in the service of learning in K-12 classrooms. Constructionism focuses on the significance of culture in learning, while simultaneously offering a meaningful role for technology in learning – objects, tools, and technologies offer new modes and means for learning through constructing, designing, and making. To support constructionism in the classroom, I further argue that we need to focus on supporting teachers, who necessarily serve as the agents of classroom-level innovations (Borko 2004: 3).

"6 Responding to the call from Hugh Gash (2014: 306) that "the striking educational question to ask now is how to think about the teachers’ role in the 21st century," I explore a central question: How can we support teachers to engage with constructionism as a way to think beyond a technocentric view in the classroom? I approach this work from the perspective of a designer, using the process of supporting teachers working with the Scratch programming language in K-12 classrooms as a central example, highlighting the complexities and tensions involved in helping teachers through professional development opportunities. For the past seven years, my research has focused on studying and supporting constructionist approaches to learning with the Scratch programming language, particularly in formal learning environments such as K-12 classrooms. The ideas in this article draw on reflections from six years of the ScratchEd project, which includes interviews with 30 teachers, and observations from teacher professional development events and an online community of educators.

"7 The remainder of the article is organized into four sections. In the first section, "Defining constructionism," I provide a definition of constructionism as a set of classroom practices. In the second section, "Supporting teachers," I outline the elements of a model that I have been developing to support teacher learning, including an online community, participatory meetups, and an introductory workshop. In the third section, "Negotiating tensions," I discuss the tensions that I have experienced in developing the model and offer examples of how I have negotiated those tensions in each of the three elements of the model. In the conclusion, "Beyond technocentrism," I end with comments on the relationship between technologies and theories of learning.

Defining constructionism

"8 Although constructivism is a term familiar to most teachers, constructionism is not. I frequently share a favorite excerpt from Yasmin Kafai and Mitchell Resnick as definition.

"9 Constructionism is grounded in the belief that the most effective learning experiences grow out of the active construction of all types of things, particularly things that are personally or socially meaningful (Bruckman 2006; Papert 1980), that are developed through interactions with others as audience, collaborators, and coaches (Papert 1980; Rogoff 1994), and that support thinking about one’s own thinking (Kolodner et al. 2003; Papert 1980). I argue that these four aspects – learning through the activities of designing, personalizing, sharing, and reflecting – are essential to the design of constructionist learning environments. Each of these activities has an extensive literature associated with it; in the following sub-sections, I draw attention to a few of the key ideas, themes, theories, and concepts that have been most helpful to my understandings.

Designing

"10 There are competing narratives about the relationships between young people and digital technology. One popular narrative is that of the “digital native” – kids who were “born digital” and belong to the “digital generation” (Palfrey & Gasser 2008; Prensky 2001; Tapscott 2008). This narrative is often centered on an assumed familiarity and fluency with computation, the idea that young people have innate understandings that elude adults – parents and teachers, cast as “digital immigrants.”

"11 Descriptions of digital natives’ activities and participation that draw on exemplars or ideal types, such as Henry Jenkins et al.’s (2006) “core media literacy skills” and Mizuko Ito et al.’s (2009) “hanging out, messing around, and geeking out” participation modes, have elicited criticism for misrepresenting the “often unspectacular” interactions between young people and technology (Selwyn 2009: 364).

"12 Digital native narratives tend toward an exaggerated or undifferentiated view of technology use, in which all forms of interaction with digital technologies are valuable and all types of participation offer equally interesting opportunities for learning. David Buckingham provided a broad critique of the young-person-as-technology-elite narrative, arguing that the narrative is less of an observation than an aspiration for creative uses of technology – that positioning young learners as digital natives is “not a description of what children or young people actually are, but a set of imperatives about what they should be or what they need to become” (Buckingham 2007: 15).

"13 In particular, creative activities such as designing and making with digital technologies are relatively uncommon in the practices of young people. This is partly due to the nature of the technologies themselves – for example, the preponderance of “edutainment” software, and the paucity of construction-oriented software (Ito 2009). But it is also partly due to the lack of visibility and value in school culture (and beyond) of design thinking, with young people reluctant to see the complexities of design activities “as opportunities rather than as things to be avoided” (Fischer 2002: 25).

"14 Constructionist approaches to learning, which value learning through de-
sign activities, respond by engaging young people in iterative thinking, problem-solving practices, and critical creativity, which serve as foundations for learning (Harel & Papert 1990; Kafai 1995; Kolodner et al. 2003; Krajcik & Blumenfeld 2006). Designing necessitates the ability to identify and negotiate constraints, clarify and manage ambiguity, and, fundamentally, persist and engage in hard work (Fischer & Nakakoji 1997; Razzouk & Shute 2012; Sawyer 2006; Seiter 2008).

Personalizing

In contrast with the structures common in modern education, such as large class sizes and homogeneous curriculum, constructionism recognizes the importance of the individual. Personalizing, as a constructionist aim, means that the design of learning experiences should consider how to engage an individual learner on multiple levels, including cognitive and affective.

The cognitive perspective on personalization traces back to constructionism’s main influence – Piaget and constructivist assumptions about learning. In constructivist theories of learning, learning is not something done to learners, but rather something done by learners. Learners are not filled with knowledge and new ideas by the world around them; they engage in processes of adaptation. Engaging with new ideas leads to assimilation, by taking new ideas and connecting them to already-established understandings – or to accommodation, by modifying already-established understandings in consideration of new ideas (Ackermann 1996; Koschmann et al. 1996; Piaget 2007; Kieger 2005). Understanding and supporting learning necessarily means creating opportunities to make sense of the individual, personal connections that learners form to what they are learning.

Part of this sense-making involves thinking about differences in individuals’ learning styles and self-concepts, and recognizing that there is not one way or style of learning. There are numerous examples of frameworks that seek to extend the ways in which learners see themselves and are seen by others. Howard Gardner’s multiple intelligences (1983, 1991, 1999) aimed to dislodge some of the privilege associated with linguistic and logical/mathematical capacities, by drawing attention to other capacities, such as musical, spatial, and inter/intrapersonal. Carol Gilligan’s (1982) reinterpretation of Lawrence Kohlberg’s stages of moral development sought to displace masculinist assumptions about self versus other. Carol Dweck’s (2000) entity and incremental theories of intelligence provided ways of thinking about how to support students productively, by challenging assumptions about ability, success, praise, and confidence. Sherry Turkle and Seymour Papert (1990), in critiquing Jean Piaget and Bärbel Inhelder’s privileging of formal reasoning, argued for recognition of both bricoleur and planner approaches, particularly in the planner-dominated culture of computation. These frameworks deserve the attention of learning environment designers, and should encourage thinking about how individual learners are more or less productively engaged by different strategies.

Sharing

Learning and development have important individual components (as articulated in “Personalizing,” from the perspective of Piaget’s work). But they are also deeply social processes. Lev Vygotsky extended the Piagetian framing of the individual’s cognitive processes by introducing the notion of the zone of proximal development (ZPD), defined as the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers.\**\ (Vygotsky 1978: 86)

Vygotsky’s notion of the ZPD expanded the boundaries of individual cognition, including other people and their abilities as part of an individual’s capacities for taking on challenges of increasing difficulty (Cole & Wertsch 1996).

Theories about communities of practice and situated learning further extend thinking about how others support learning, in particular, how community settings can provide access to other learners and artifacts (Brown, Collins & Duguid 1989; Lave & Wenger 1991; Rogoff 1994). In this literature, apprenticeship is a recurring metaphor for the type of learning that can take place, introducing new ways of thinking about the learner and the people around the learner who are helping them (Collins 2006; Lave & Wenger 1991; Wenger, McDermott & Snyder 2002). Learners are gradually folded into relationships with other learners, understandings of the enterprise of the learning, and familiarity with the objects and practices of the community – learning from those with greater experience and expertise, in a process that Jean Lave and Etienne Wenger (1991) described as legitimate peripheral participation.

More recent research has described the ways in which the social nature of learning serves as essential motivation and support for young people’s participation in digital culture, particularly in the context of online interactions (Buckingham & Willett 2006; Ito et al. 2009; Jenkins et al. 2006). Whether hanging out with friends or playing games or remixing media, having access to others makes for better participation, as young people are able to support each other in understanding practices and norms. Amy Bruckman’s (1998, 2006) work described the cognitive, social, and psychological benefits that an online community provided for individual learners in constructionist activities. From technical support to emotional support, having access to others bolstered individuals’ capacities for creative work. And the social nature of learning is not reserved for kids – teachers as learners can similarly benefit from access to others (Fishman & Davis 2006).

Reflecting

In Mindstorms, Papert (1980) described his vision of children as epistemologists, wherein kids use computers as an opportunity to explore their processes of thinking. Programming becomes a context for thinking about thinking, and the Logo programming language serves as something to think with.

The activities of designing, personalizing, and sharing invite learners to ask numerous questions of themselves, of what they are doing, and of how they are think-
ing. What do I want to create? What do I need to create? What do I need help with? Why did that work as I expected it to? Who might help me? Who might I help? How might I better approach all of these questions? These types of questions represent opportunities for kids to reflect on their activities and to think about their thinking – for kids to engage in metacognitive processes.

Numerous frameworks have been proposed for articulating metacognitive processes, and several highlight the temporal dimension of metacognition – when the thinking about thinking takes place in relation to action. Donald Schön (1983) articulated a difference between reflection-in-action and reflection-on-action. John Bransford et al. (2000) emphasized a similar separation, drawing out self-regulation and reflection from metacognition, with the former focusing on activity planning and monitoring, and the latter focusing on assessment and evaluation of activity performance. John Flavell (1979) described metacognition as the interplay between goals (what the learner is trying to achieve), strategies (how the learner tries to achieve it), metacognitive knowledge (what the learner knows about learning), and metacognitive experiences (how the learner thinks about that knowledge in action).

The significance of metacognition in a variety of learning and cognitive processes has long been recognized (Flavell 1979). The ideas of self-control and self-instruction described by Flavell (varyingly referred to as self-control, self-instruction, self-regulation, self-efficacy, and self-directedness) speak directly to the underlying importance of learner agency in constructionism. Albert Bandura (1997) highlighted the significance of these capacities, for supporting learning as both a lifelong and long-time activity.

Development of capabilities for self-directedness enables individuals not only to continue their intellectual growth beyond their formal education but to advance the nature and quality of their life pursuits. Changing realities are placing a premium on the capability for self-directed learning throughout the life span. The rapid pace of technological change and the accelerated growth of knowledge require continual upgrading of competencies if people are to survive and prosper under increasingly competitive conditions. (Bandura 1997: 227)

Supporting teachers

A description of constructionism, no matter how detailed, is insufficient for teachers to translate the theory of constructionism as educational philosophy to the practice of constructionism in designing learning experiences. To better understand what is required to translate theory into practice, I have been studying and supporting K-12 teachers who include Scratch and the Scratch online community (http://scratch.mit.edu) in the learning experiences that they design.

Scratch is an authoring tool that enables people to program their own interactive media projects by snapping blocks of instructions together (Resnick et al. 2009). The authoring environment is situated within an online community, where creators are able to share their projects with others (Brennan 2014; Brennan & Resnick 2013). Since Scratch’s launch in May 2007, more than 9.6 million projects have been created and shared by more than 6.7 million registered members.

Scratch draws on the traditions of the Logo programming language and community for intellectual inspiration (Brennan 2013). The intentions and aspirations for how Scratch might be employed in learning environments are grounded in Papert’s vision for the types of relationships to expect and encourage between young people and computers.

In most contemporary educational situations where children come into contact with computers the computer is used to put children through their paces, to provide exercises of an appropriate level of difficulty, to provide feedback, and to dispense information. The computer programming the child. In the LOGO environment the relationship is reversed: The child, even at preschool ages, is in control. The child programs the computer. (Papert 1980: 19)

But a tool itself cannot dictate how it is used in a particular environment, despite the intentions of the tool’s designer (Scardamalia & Bereiter 1991). While constructionist aspirations shaped the design of Scratch, constructionism can all too easily be replaced by didacticism and technocentrism in the classroom – for example, through paint-by-numbers lessons that emphasize “mastery” of the tool at the expense of learner agency and metacognition.

In response, my research has focused on how to support K-12 teachers working with Scratch in gaining comfort and familiarity with constructionist classroom practices and the use of technology in support of learning.

The teacher professional development (PD) literature offers guidance for how to design this support. Qualities of effective PD for teachers include: extended time, moving beyond the one-shot model of teacher learning; attention to content; experiences grounded in teachers’ contextual needs, such as demands of standards; access to resources and “educative materials” related to practice; encouraging reflection and critical interactions; and framing teachers as learners (Ball & Cohen 1999; Fishman, Davis & Chan 2014; Hill 2007; Hill, Beisiegel & Jacob 2013; Webster-Wright 2009; Wetheimer 2008).

Three qualities of PD that were recurrently identified in the literature as important to effective PD (particularly when teachers were engaging in new types of knowing and doing) included: (1) modeling learning, (2) engaging teachers in experiences themselves as learners, and (3) supporting social interactions among teachers. As Hilda Borko summarized:

There is agreement among the reports that high-quality PD incorporates processes such as modeling preferred instructional strategies, engaging teachers in active learning, and building a professional learning community. When teacher educators model instructional strategies, PD participants have the opportunity to experience these strategies as learners, and then reflect on their learning and on the effectiveness of the strategies from the perspective of teachers. This type of approach is particularly important in times of reform, when teachers frequently are being asked to teach in ways that are substantially different from how they were taught or how they learned to teach. (Borko, Jacobs & Koellner 2010: 550)

Guided by these qualities of effective PD and responding to the needs and interests of teachers, I have been developing a model of professional development to
support teachers’ understandings and explorations of constructionism with Scratch. The model, named ScratchEd, creates opportunities for communities of teachers to engage in the same designing, personalizing, sharing, and reflecting activities that are essential for young people. ScratchEd includes three primary elements – an online community, monthly face-to-face meetups, and an online workshop – and is rooted in a central assertion: teachers should have learning experiences that are comparable to their students’ learning experiences, situated within a supportive community of fellow teachers. This assertion has served as a core design principle for the ScratchEd PD model, the elements of which I will now describe in more detail.

**ScratchEd online community**

« 33 » Although the Scratch online community has a large and active membership, it was not designed to support educators. It was designed for people who want to create and share projects, while educators are primarily concerned with helping other people create projects. Based on the expressed interest of K-12 teachers and motivated by the community of practice literature – a model in which teachers as learners have access to peers, shared goals, and resources (Barab, Barnett & Squire 2002; Wenger 1998) – I developed the ScratchEd site for educators (http://scratched.gse.harvard.edu).

« 34 » Teachers interested in or already actively working with Scratch can use ScratchEd to share stories, exchange resources, ask and answer questions, and find other educators. In designing the ScratchEd site, I was inspired and influenced by others’ work in online communities for educators, including Tapped In (Farooq et al. 2007), KNOW (Brunvand, Fishman & Marx 2005), WIDE World (Wiske, Perkins & Spicer 2006), and Inquiry Learning Forum (Barab, Makinster & Scheckler 2003).

« 35 » ScratchEd was publicly launched in August 2009. In the six years since its launch, more than 16500 educators from around the world have joined the community, and have contributed more than 270 stories, 790 resources, and 5000 discussion posts. Over the past year, the site has received an average of 112500 page views from 24500 unique visitors per month, predominantly from the United States. The site encourages participation and contributions from members; resources and stories that illustrate and support constructionist approaches are highlighted through curation.

**Scratch educator meetups**

« 36 » The ScratchEd online community, although supporting teachers’ needs for resources and connections, cannot provide constructionist experiences. I wanted to better support the experiential dimensions of teacher PD – supporting teachers in knowing what constructionist learning experiences might look like and feel like. This desire led to the development of “meetups.” Scratch educator meetups derive from approaches to teacher learning that emphasize teacher agency (which places teacher thinking, ambitions, and actions at the center of the learning), rather than teacher training (which often frames the teacher-learner as passive in relation to the learning). The meetups have been inspired by participatory teacher learning models such as lesson study groups (e.g., Doig & Groves 2011; Fernandez 2010; Watanabe 2002), professional learning networks (e.g., Alderton, Brunsell & Bariexca 2011; Fulton, Doerr & Britton 2010), and EdCamps (e.g., Boule 2011; Swanson & Leanness 2012).

« 37 » The monthly meetups began in Cambridge, Massachusetts in December 2010 as a way for educators interested in Scratch to connect with their peers, support each other’s learning about Scratch in a classroom setting, and share their experiences. The meetups are three hours in duration, take place on Saturday mornings, and are structured in three parts. Part one involves networking and introductions, in which people get to know each other or (depending on the number of repeat attendees) catch up. Part two consists of self-organized breakout sessions. The group, which ranges in size from 10 to 50 people, collectively negotiates different tracks of learning, focus, and activity, and then breaks out into smaller groups to pursue those interests. Part three, which occurs over lunch, involves reporting out from the breakout groups, sharing experiences in a show & tell format, and general group updates and announcements.

**Creative Computing Online Workshop**

« 38 » ScratchEd meetups are geographically constrained, accessible only to those in and around Boston. In response, with support from Google’s CS4HS program and motivated by curiosity to explore large-scale online learning environments as sites of constructionist learning experiences, I led the development of the Creative Computing Online Workshop (CCOW), an open online learning experience. The workshop was built using Google’s Course Builder platform, which provided the infrastructure for creating an online course.

« 39 » CCOW (http://creative-computing.appspot.com) was organized as an experience for teachers to learn about Scratch, both as a tool and as an approach to learning. CCOW was hosted for six weeks, from June 3 until July 12, 2013. Approximately 2100 people from all around the world enrolled in the workshop, with 51% of those enrolled indicating that they intended to participate beyond “just browsing.”

« 40 » During the workshop, participants engaged in a variety of activities. They created Scratch projects, working with the latest version of Scratch (Scratch 2.0), from focused debugging challenges to more open-ended design explorations. They maintained online design journals that served as a record of and reflection on their participation throughout the workshop. They defined and pursued independent learning projects, such as designing curriculum, hosting workshops for kids, and exploring the connections between programming and art. They interacted with workshop colleagues through comments on design journals and discussions in the course’s online forums. Over the six weeks of the workshop, CCOW participants watched workshop videos 24000 times, created 4700 Scratch projects, wrote 3500 discussion posts, and shared 180 final projects.

**Negotiating tensions**

« 41 » Having worked on the development of the ScratchEd model to support teachers’ explorations and experiences with constructionist approaches in the classroom for the past several years, I am often asked, “What lessons have you learned from your...
work?” I have come to appreciate that my experiences and understandings are more aptly described as “tensions negotiated” than “lessons learned.” These tensions are developed from thematic coding of my design notes, memos on intentions for and experiences with the designs described in the previous section, as well as interview data from teachers who variously participated in the online community, meetups, and online course. They are grounded in the complexities that arose from trying to support teachers’ experiences with designing, personalizing, sharing, and reflecting within a professional development learning context. In this section, I describe five of the most pressing tensions, illustrated with examples from my experiences as a designer of the ScratchEd model of professional development for K-12 teachers.

Tension between tool and learning

Constructionist approaches to learning emphasize the importance of culture over content and learning over tool, and are well aligned with aspirations to disrupt technocentrism in the classroom. All three elements of the ScratchEd PD model prioritize pedagogical knowledge over content knowledge. That is, the online community, the meetups, and the online workshop emphasize thinking about constructionist approaches to learning over thinking about the mechanics of Scratch as tool or thinking about particular computer science concepts. But emphasis on content can also be important to supporting teachers’ learning and development (Fishman, Davis & Chan 2014; Hill, Beisiegel & Jacob 2013), and for some teachers, a lack of content knowledge can undermine confidence, discouraging them from using Scratch with their students. A balance must therefore be achieved between knowledge about the tool and understanding of how to engage in creative design activities, using the computer for personal expression and problem solving.

Within the elements of the ScratchEd model, I negotiate this tension in different ways.

Online community

A wide range of resources are posted by my research team and by members of the ScratchEd community. We curate resources for teachers that strike a balance between tool and learning, promoting them to have greater visibility within the online community.

Meetups

The participatory nature of the meetups invites a wide range of potential topics and formats. At the beginning of each meetup, we provide examples of potential breakout sessions (which range from more tool-centric, to more learning-centric, and everything in between). Seeding the collective brainstorming with examples for the breakout sessions helps manage the balance.

Online workshop

Reflective journaling is a critical component of participation in the online workshop. Teachers’ design journals are framed as a place to reflect on artifacts and activities, with prompts encouraging them to question the implications for their teaching practice and students’ learning.

Tension between direction and discovery

Teacher-learners (and all learners, more generally) flourish when they are invited and supported to take ownership of and responsibility for learning goals, instead of primarily following the ambitions and direction of others. But in order to achieve their goals, learners require access to resources to support the pursuit of their pathways (Fishman, Davis & Chan 2014). In response, PD designers need to make experiences and resources available that are appropriately accessible (in format and complexity) and appropriately timed (in duration and pacing) for the learner. In doing so, the PD designers negotiate a central tension between direction (providing resources in advance, anticipating and steering learner needs) and discovery (making resources available when they are needed, in response to learner needs).

Within the elements of the ScratchEd model, I negotiate this tension in different ways.

Online community

All of the stories, resources, and forums are asynchronously available to members through various search mechanisms for self-directed support. For those who need more curated, externally-directed support, such as novices, this support is available in the form of landing pages for beginners.

Meetups

The informal nature of the meetups makes it possible for teachers to participate as needed throughout the year, and the content of each meetup is directed by the participants themselves. In the moment, participants make decisions about how directed or discovery-oriented to make each breakout session.

Online workshop

The online workshop is structured as a collection of flexible, curated pathways of resources, within a directed six-week participation window. After the synchronous window, the resources of the online workshop (e.g., activity descriptions, tutorial videos) continue to be available for self-directed support.

Tension between individual and group

As described in “Defining constructionism,” learning is not an individual process – learners can benefit from being connected with others (Brown, Collins & Duguid 1989; Lave & Wenger 1991; Rogoff 1994). These connections can take different forms, with others potentially serving key roles as advisors (e.g., providing advice for challenges), as collaborators (e.g., jointly pursuing a learning goal), as audience (e.g., showing appreciation for creative work), and/or as advisees (e.g., someone with whom to share one’s understanding). Individuals unfamiliar with social learning, however, may resist these opportunities, seeing them as not aligned with or even antithetical to their own interests and goals. For the PD designer, cultivating connections between learners and others involves (at least) two components: (1) helping teachers identify potential connections (i.e., matchmaking), and (2) supporting positive interactions within those connections (i.e., respectful, productive, and mutually beneficial). Designers can introduce structures that support connection-making processes (e.g., introducing learners to those who
have compatible and complementary interests, or grouping learners with those who have divergent interests as a way to broaden learners’ perspectives).

« 53 » Within the elements of the ScratchEd model, I negotiate this tension in different ways.

Online community

« 54 » Members of the online community have a personal profile, which offers information about their background and interests. People can explore profiles through a faceted search mechanism. For example, displaying all members who teach secondary-school children, live in Europe, focus on mathematics education, and speak Dutch. This helps members view the larger community of 16k+ members as collections of smaller interest groups, hopefully minimizing feelings of being lost in the larger community.

Meetups

« 55 » A portion of each meetup is dedicated to networking and collaborative schedule-making to accommodate a wide range of interests and to support connections among participants. Exploring those interests is further supported through the breakout sessions, where participants are encouraged to freely move between sessions to follow their interests and needs.

Online workshop

« 56 » Teacher participants were paired with other workshop participants to provide comments and feedback on each other’s projects and design journals. We used feedback protocols as a mechanism for encouraging critical and respectful interactions.

Tension between expert and novice

« 57 » Closely related to the tension between the individual and the group is the tension between individuals within a group as they take on roles of “expert” and “novice.” Our work has involved teachers with a range of backgrounds – from teachers who have extensive classroom experience to those who are just starting their practice, teachers who have long-adopted constructionist practices to those with more didactic or teacher-centric approaches, and teachers who have extensive experience with computer science and Scratch to those who describe themselves as terrified by computers. Across these dimensions, there are multiple notions of who is an “expert” and who is a “novice.” But while it can be beneficial to have participants with a broad variety of expertise, relying too extensively on the expertise of participants can be problematic. First, in participatory models of learning, those with greater expertise or confidence can be denied opportunities to extend their own learning. Second, expertise in one aspect of practice does not imply expertise across all aspects of practice. Those cast as “experts” may unintentionally encourage “incongruent adaptations” (Lin & Fishman 2009) or “lethal mutations” (Brown & Campione 1996) of constructionist practices. Accordingly, PD designers should consider how to disrupt conventional notions of expertise and invite broad participation.

« 58 » Within the elements of the ScratchEd model, I negotiate this tension in different ways.

Online community

« 59 » In the early days of the discussion forums, we were careful not to respond too quickly to questions. By creating the space for others to respond, my research team’s anticipated expertise was supplanted by the expertise of community members.

Meetups

« 60 » The breakout sessions are explicitly framed as not didactic. Breakout sessions should not be lectures; they are about mutual exploration and sharing. Setting this cultural expectation disrupted ideas about who was the “expert” and who was the “learner,” creating the possibility for more fluid notions and performances of expertise.

Online workshop

« 61 » Participants in the workshop were encouraged to make all of their work public, whether in the form of their Scratch media projects or their reflective journal writing. This culture of openness made it possible for all participants to peek into and learn from others’ processes. Novices learned from the more sophisticated approaches of those more expert; experts were exposed to a wider range of implementation strategies.

Tension between actual and aspirational

« 62 » In many ways, constructionist learning experiences are fundamentally at odds with the lived reality of K-12 education. The lack of resources, lack of time, lack of administrative support, lack of meaningful metrics for assessment and evaluation, and even a lack of interest from learners, can all contribute to an (at times) overwhelming sense of challenge. A tension exists for PD designers, then, between the actual and the aspirational, to determine what is feasible given current constraints and what might be imagined for the future(s) of learning. Inherent to the role of a PD designer is to offer a sense of the possible, to share what learning could be like. This stance often conflicts with barriers perceived or imagined by teacher participants, and will involve sincerely engaging with concerns – the collection of “but…” statements, such as “I’d like to do that, but…”, “That seems interesting, but…” or “I see how you could do that, but…”

« 63 » Within the elements of the ScratchEd model, I negotiate this tension in different ways.

Online community

« 64 » The Stories section of ScratchEd most directly contributes to this balance. In the initial days of the online community, we interviewed teachers who were working with Scratch in the classroom and wrote stories about their activities, highlighting the opportunities and acknowledging the challenges. These stories illustrate the possible, while respecting the lived reality of teachers’ experiences.

Meetups

« 65 » In co-designing the breakout sessions, teachers have the opportunity to incorporate the daily contextual demands of their practice into session activities. By engaging with colleagues in critical and reflective discourse about their experiences, teachers are able to surface their concerns and challenges, while making plans and taking actions for change and reform.

Online workshop

« 66 » In addition to the reflective design journal, workshop participants defined and pursued a self-directed project. The pur-
Beyond technocentrism

The specific tensions discussed in this work are particularly salient for constructivist and constructionist approaches to learning. Constructivist approaches to PD (which, as Hilda Borko, Jennifer Jacobs, and Karen Koellner (2010) argued, represent the direction that teacher professional development is – or at least should be – headed in, given what we know about learning more generally from educational psychology and the learning sciences) and constructionist approaches to PD, invite the type of “disequilibrium” (Ball & Cohen 1999: 14) necessary for teacher learning. Each of the five tensions presented here highlights some dimension of the disequilibrium present in constructivist/constructivist learning environments: the role of content, the role of learner autonomy and agency, the situated and social role of learning, the role of expertise, and the role of contextual demands.

In the inaugural issue of Constructivist Foundations, in response to the question “What is constructivism?,” Alexander Riegler outlined ten points of a “constructivist program.” The sixth point in his program was a move “from the world that consists of matter to the world that consists of what matters” (Riegler 2005: 4). This move from matter to what matters is also central to a similarly framed “constructionist program.” Papert’s Computer Criticism vs. Technocentric Thinking illustrates this shift from matter to what matters, from computer to learning culture.

The context for human development is always a culture, never an isolated technology. In the presence of computers, cultures might change and with them people’s ways of learning and thinking. But if you want to understand (or influence) the change, you have to center your attention on the culture – not on the computer.® (Papert 1987: 23)

But equally central to a constructionist approach is the return trajectory, the interplay between matter and what matters. The “matter” (i.e., the technology) makes possible the “what matters,” enabling learners to build, make, create, and play, externalizing and expressing their ideas, connecting learners to the world beyond themselves and their classrooms, connecting learners to each other, and forming traces of learning that can serve as the basis of metacognitive activities. In a constructionist learning environment, the “what matters” depends on “matter” in an important way as a means of engaging in the work of design and construction.

Acknowledgements

The author wishes to thank the guest editors for their encouragement and persistence, as well as the OPC respondents for their thought-provoking comments. This material is based on work supported by the National Science Foundation under grant no. 1019396, by the Code-to-Learn Foundation, and by Google. Any opinions, findings, and conclusions or recommendations expressed are those of the author and do not necessarily reflect the views of the NSF, the Code-to-Learn Foundation, or Google.

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Open Peer Commentaries on Karen Brennan’s “Beyond Technocentrism”

Embedding Technology in Pedagogy

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Brennan describes strategies designed to help teachers use Scratch in their classrooms, emphasising interfaces between the tool and its users, between users and between hope and happening. Previous work with similar aims identified apparently significant cultural approaches to initiating constructionist practice. Questions arise about the development of practice from technocentric to pedagogic over time that may have some answers in the data accumulated.

At present we are part of a European Union-funded project (TEALEAF) designed to introduce “serious games” in the context of science education to teachers in five countries (the Czech Republic, France, Ireland, Slovenia, and Spain) with a view to teaching and learning about biodiversity through the medium of Scratch-based apps. Our project is based in a previous approach that sought to promote constructionist practices in primary and secondary classrooms in teaching science. To assess these differences we used the Constructivist Learning Environment Survey (CLES), designed by Peter Taylor and Barry Fraser and others (1997). We found significant differences apparent in teachers’ approaches in each country and at each level of schooling within each country (Groupe Interuniversitaire Projet Sophia 2009; Gash & McCloughlin 2010). We believe these data are useful in thinking about Karen Brennan’s work, particularly as we strove to employ apps as a means to learn science and challenge technocentrism in a different way.

Brennan has identified five “interfaces” as crucial in helping the teachers she worked with to use the Scratch tool. These are acutely in tune with the difficulties of introducing new technologies in classrooms and sensitive to the ways both teachers and projects work. Two of these, the interfaces between “tool and learning” and between “expert and novice” offer an opening to difficulties teachers may have in changing their ways of working, ways that may depend on their beliefs about teaching (Sharkey 2014). These beliefs are related to the ways teachers teach and are reflected in their attitudes to constructivist teaching activities.

In our previous European Union-funded project (SOPHIA), we found that Irish primary teachers, in contrast to secondary teachers, were more attuned to the personal relevance of learning and the importance of students communicating about what they know (Gash & McCloughlin 2010). These are features of constructionist teaching that vary within the teaching profession and that seem crucial in implementing constructionist approaches. More use of methods requiring constructionist outcomes might facilitate this dimension of constructionist practice. Was this a dimension that varied in the author’s sample, or was it so necessary for the methods used that it was taken for granted and obscured?

The five interfaces are related to implementing Scratch technology in classrooms. So we would like to ask Brennan how the importance of these interfaces varies over time? We assume that the tension between tools and learning is quickly resolved, and that ahead of time and just-in-time issues are resolved by teachers as they become more experienced. However, group relations and expert novice relations intuitively seem less easy to resolve. Was this the case?

In another study, Deirdre Butler (2004), working with the former Media Lab Europe in Dublin, believed that offering teachers challenges with digital technology like those offered to children would provide teachers with insights into ways to structure learning experiences for children. Butler found that it was helpful to categorize teachers on two categories: (a) fluency with digital technologies (high and low) and (b) how the teachers conceptualized learning (instructionism and constructionism). These were dimensions on which Butler could place particular teachers and seemed comparatively stable dimensions of a teacher’s approach. They seem to relate closely to the issues implied in the tensions between “tool and learning,” “expert and novice” and “actual and aspirational.” However, Butler’s experience was that they were relatively stable dimensions of a teacher’s approach. In Brennan’s data, are there insights into ways to help teachers change their approach?

We also worked with Media Lab Europe and explored the tension between two biological environments: the “virtual” and the “real” (Cherubini, Gash & McCloughlin 2008). However, such a tension appears so great for some teachers that they shy away from digital technology altogether.

Information and communications technological pedagogical content knowledge (ICT-TPCK) as a concept has been developed by Charoula Angeli and Nicos Valanides as:

http://www.univie.ac.at/constructionism/journal/10/3/289.brennan
the ways knowledge about tools and their affordances, pedagogy, content, learners, and context are synthesized into an understanding of how particular topics that are difficult to be understood by learners or difficult to be represented by teachers can be transformed and taught more effectively with technology in ways that signify its added value." (Angeli & Valanides 2009: 154)

Punya Mishra and Matthew Koehler (2006) examined three key components of ICT-TPCK, namely:
1 competing resources; and
2 lack of confidence both in the science content and
3 the competency in using digital learning.

These are often too disparate to synthesize, since synthesis requires components that coalesce at some point, so consideration of the stability of the dimensions of a teacher's approach is prescient since it was a content focussed study – learning about science through technology. However, for Brennan, technology is the goal of the learning itself and this might also be considered as technocentric, except that Brennan uses Scratch as an affordance to a higher-order thinking processes such as “creating,” and “middle-order” thinking processes involved in social interaction. The three experiments outlined by Brennan were designed to disrupt technocentrism, but how successful was that?

Brennan’s work could be viewed within the framework of ICT-TPCK, and we particularly support her approach of focussing on pedagogical knowledge as opposed to content knowledge. However, we would suggest that there is a close relationship between the two and teachers may on the one hand find dealing with pedagogical issues simpler, whilst their externally imposed learning outcomes may require an emphasis on content. Her work on challenging "technocentrism" is prescient since the constructivist is concerned with overall cognitive and emotional development not governed by an external objective reality. Technology can sometimes become such a reality, and in doing so, the user becomes the servant, and technology becomes the beginning, middle and end of learning.

Acknowledgements
This project was funded with support from the European Commission. SOPHIA COMENIUS Project 128958-CP-1-2006-1-FR-COMENIUS-C2-TEALEAFERASMUS-PLUS Project 2014-FR01-KA201-008559. Disclaimer: The content of the document reflects the views of the authors only, and the Commission cannot be held responsible for any use that may be made of the information contained therein.

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Received: 20 May 2015
Accepted: 15 June 2015

Changing Teacher Beliefs: Moving towards Constructionism

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>Upshot • If we are to move beyond technocentrism, we need not only to equip teachers with pedagogical approaches but to support a change in their beliefs, values and assumptions. While factors such as assessment practices and institutional norms can limit the impact of professional development by considering the ways in which teachers form their teacher-identity and the factors that can motivate change, we can begin to develop approaches to professional development that can have lasting impact on teachers and their learners.

Teacher-role identity is influenced by the experiences that teachers have had as learners themselves. Many of our current teachers experienced a technocentric integration of technology into their own education and so this may be seen to be an acceptable norm. In asking how we can defend against technocentrism, Karen Brennan suggests that an extreme approach is to exclude digital technologies from core classroom experiences. Yet, unfortunately, this is not an uncommon practice. There can be a tendency to treat ICT or computing as discrete subjects, taught in silos by experts, particularly in secondary-level education. This is emphasised by the allocation of a specific timeslot in the timetable and an expectation that the “skills” are learnt there. This is just one way in which the “invisible curriculum” can be seen not only to influence learning but also teaching. There can be an expectation that students will have developed the skills required, either from these discrete classes or from their use of technology at home. This can result in a belief that teachers need not integrate the use of technology into learner-centred approaches as that “Key Skill” has been covered by someone else (in much the same way as numeracy and literacy skills are assumed to be covered in maths and English classes). Thus, in the classroom, ICT is used for ICT’s sake (Bertam & Waldrip 2013), in a teacher-centred approach and to “tick-off” a requirement. On the other hand, it can also result in an assumption that students are able to use the technologies teachers ask them to, both effectively for learning and responsibly, when they may never have encountered them, least of all used them to learn with or through. Thus the teacher may find themselves frustrated at the lack of student progress on specific tasks, resorting to technocentric teaching of skills or avoidance of technology altogether.

One approach to resolving technocentric teaching is to restructure the school day, providing support for teachers to collaborate, teach in teams and develop interdisciplinary lessons. This is used in the Bridge21 model for teaching and learning (Conneely et al. 2015), which emphasises the use of technology to mediate learning but is not dependent upon it. In a Bridge21 lesson, learners collaborate in teams in

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which technical skills are developed alongside subject-specific knowledge. There is no expectation that learners will have separate ICT “training” to develop skills. Rather, skills are developed as required to facilitate the completion of projects. Importantly, the technical skills, along with developing knowledge and understanding, are held at the level of the team, not requiring any one individual to know “how-to” or for the whole team to gain, necessarily, a specific skill.

« 3 » Maria Daskolia, Chronis Kynigos and Katerina Makri (this issue) present an excellent example of some of the complexity that surrounds the use of technology to support learning through collaborative constructionist activities. The article highlights that the technology had to be learned and learners skills in the use of specific applications have the potential to constrain the final digital story that learners created. However, an interesting question remains – did the lack of these skills become a barrier to learning? As Brennan suggest, a technocentric view of technology in the classroom would lead to the answer “yes.” However in this constructionist learning activity, learners were free to choose the technologies they felt would enable them to demonstrate their understanding and create their digital story. While a lack of technical skills may have limited their creative vision, there is no evidence to suggest it limited learning.

« 4 » So how can we best support teachers through professional development to move away from technocentric approaches to the use of technology in the classroom? It is essential that in any professional development programme, we address the underpinning ideas, beliefs and values of teachers, which Robin Alexander (2008) describes as informing, justifying and sustaining their existing practices. Pre-existing teacher-role identity (Knowles 1992) influences these ideas, beliefs and values, which are reinforced by pressures from national assessments and cultures of compliance within schools. These factors can limit the effectiveness of any new initiative and limit the potential for teachers to develop their practice beyond existing norms.

« 5 » Caroline Daly, Norbert Pachler and Caroline Pelletier (2009), in their review of CPD in ICT for the UK agency BECTA, recognise the importance of teachers taking personal responsibility for their learning and for CPD to be flexible enough to support personal learning journeys. Initial education and professional development courses can be seen to present an idealistic view of teaching and learning that does not always take into consideration curriculum and assessment pressures or the normalising effect of individual institutions. One approach that allows us to address this, and resonates with Brennan’s article, is that of TeachMeets, which provide opportunities for professional development through a network of teachers who meet, share and discuss their practice, potentially alleviating these concerns. As a route to understanding the practices of others, this also has the potential to influence teacher-role identity.

« 6 » A final factor that Brennan and others may wish to consider in future work is the influence of student outcomes on teachers’ ideas, beliefs and values. Thomas Guskey (2022) identifies positive changes in student outcomes as one motivating factor for teachers to change their own practice. While this may be the ultimate aim of CPD, I suggest that we should engage this motivational factor early on in the professional development process, demonstrating positive outcomes for students’ learning at the beginning of the CPD process. This needs to be facilitated in an authentic manner that resonates with teachers’ professional practice, is contextually sensitive and ideally provides an opportunity for teachers to observe and reflect upon the activities and outcomes for their learners without the distraction of managing learning.

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Received: 8 June 2015
Accepted: 18 June 2015

Embedding Inquiry and Workplace in a Constructionist Approach to Mathematics and Science Teachers’ Education

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> Upshot: Brennan describes ways by which teachers can be supported to bypass a technocentric view of learning with technology in the classroom, from a constructionist perspective. She reports on the development of a corresponding model of professional development (PD) by describing the elements of the model and its design principles as well as the tensions that arose while trying to support teachers’ explorations and experiences in the classroom. Questions arise about the potential of the model to be exploited to address issues underlying teachers’ professional development in different contexts.

« 1 » My choice here is to explore further Karen Brennan’s implication that the tensions she needed to negotiate with the teachers are not specific to her study and “can serve as a more general model for PD designers to scrutinize and critique” (structured abstract). I will try to link my experience as a teacher educator with Brennan’s work, based on my current involvement in the European Union-funded project “Mathematics and Science in Life” (Mas-cil). It aims to promote a widespread use of inquiry-based mathematics and science teaching in primary and secondary schools through the connection between inquiry-based learning (IBL) and the world of work (WoW). The project runs PD courses of different types (e.g., face-to-face, e-learning) in all participating (13 in total) European countries. It provides an initial body of generic classroom tasks and a document containing guidelines for teachers to develop their own tasks by connecting IBL and workplace contexts.

« 2 » A distinctive feature of implementation in Mascil is its systemic character in terms of involving different institutional
and social contexts where context-specific interventions are planned and learning communities of teachers are established (e.g., groups of teachers from a single school or neighboring schools working in the same educational level). The teachers experience IBL themselves through their involvement in iterative cycles of design-implementation-reflection. To ensure widespread participation, the project adopts a scaling-up approach aiming to engage a large number of teachers in PD activities through a pyramid model based on the use of multipliers. Being one of the multipliers in the current year, my objective was to engage a group of 12 mathematics and science teachers in integrating technology, IBL and WoW in their designs and practice under a broadly constructionist perspective. It was expected that this integration would be facilitated through the teachers’ engagement in adapting Mascil tasks or developing their own in the same spirit, based on authentic situations of workplace mathematics and/or science. The teachers were organized in a learning community that met regularly in face-to-face meetings (i.e., before and after implementations) and also had the choice to communicate asynchronously through a teachers’ communication platform. Below, I use Brennan’s categorization to describe briefly the tensions that I had to address/negotiate in the context of the community. I also highlight emergent implications/questions for in-service teachers’ mathematics and science education.

Tension between tool and learning

« 3 » In developing their designs, the participating teachers faced the challenge of addressing the need to have a balance between a focus on the use of tools in the context of specific tasks (e.g., modeling the construction of a parking) and the students’ learning of mathematics. This tension was resolved in the community through reflection on the nature of the emerging mathematical concepts in different types of designs (e.g., situation specific, open-ended) aiming to bridge school and out-of-school mathematics.

Tension between direction and discovery

« 4 » The tension between direction and discovery in Mascil was primarily based on the opposition between guided learning and IBL (Artigue & Blomho 2013). Since most of the teachers chose to develop their own tasks, they faced the dilemma of how much “exploration” could be integrated in their designs. One success that emerged in the evolution of implementation was that the newly developed tasks by the teachers were progressively less structured and more inquiry oriented. The factors that seemed to support this development were related to particular features of the PD courses such as the discussion of the IBL features of specific tasks as well as the sharing of successful implementations during the reflective sessions of the group.

Tension between individual and group

« 5 » The challenge of collaboration constituted a distinct feature of Mascil. Teachers were encouraged to develop their designs collaboratively so as to have a common ground for reflection after the classroom implementations. One emerging tension – that could probably be used to define new category or sub-category of tensions – concerned the teachers’ reluctance to collaborate with colleagues that had a different discipline from their own (i.e., mathematics teachers vs. science teachers). This tension was resolved in the PD meetings by creating a space of making connections between pieces of content knowledge involved in mathematics and science tasks and reflecting on the potential of these connections for students’ learning.

Tensions between expert and novice

« 6 » Most of the participating teachers in Mascil were experienced teachers. However, extensive classroom experience was not a condition adequate for considering these teachers as “experts.” For instance, some of them did not have a “constructionist background,” or they were never engaged in designing a classroom innovation. Thus, it was necessary for me to re-conceptualize the meaning of the opposition expert-novice in relation to the teachers’ “readiness” to adopt an IBL approach in their lesson, as a first step in the direction of recognizing the learning potential of a subsequent constructionist experience in their classroom.

Tension between actual and aspirational

« 7 » Integration of WoW in classroom tasks constitutes an innovative challenge for teachers (Wake 2014; Hoyles, Noss, Kent & Bakker 2010). There are a number of emerging tensions underlying the distance between actual and aspirational in teachers’ designs and implementations in Mascil. At the beginning of PD courses, the majority of teachers found it difficult to recognize the potential of integrating the WoW in their educational activities, invoking constraints posed by the curriculum and the available teaching time. However, the reflective practices cultivated within the group seemed to support them to appreciate gradually the potential value of integrating the WoW in their classroom teaching.

« 8 » The above description of the tensions I experienced when trying to support mathematics and science teachers to embed IBL and workplace in their teaching under a broadly constructionist approach indicates that the Brennan’s model offers us a useful lens to address the tensions inherent in the process of educating teachers to adopt constructivist/constructionist approaches in different PD contexts. A number of questions can be raised to challenge her to extend her work. What structures can support teachers to engage in designing and implementing classroom innovations under a constructivist/constructionist approach? What is the role of other resources (e.g., tasks) or contexts (e.g., workplace) that might support teachers’ constructionist approaches in the classroom? What are the features of the teachers’ learning communities and the practices in which they are engaged (e.g., types of inquiry) that can support their explorations and experiences with constructionist approaches in the classroom? How do these features/practices influence the nature of the emerging tensions in teachers’ PD activities? How can these tensions be negotiated by the teacher educators so as to enhance the teachers’ professional learning?
Acknowledgements


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Received: 15 June 2015
Accepted: 16 June 2015

Author’s Response:
The Critical Context of Teacher Attitudes and Beliefs

Karen Brennan

> Upshot • The OPC responses aptly identified numerous factors teachers encounter that can impede changes in pedagogical practice in the classroom. Although some of these factors are external, beyond a teacher’s control, I discuss one internal factor – a teacher’s attitudes and beliefs about their role and the learners they support – that was raised in the responses.

A tale of two teachers

« 1 » Several years ago, I co-facilitated an introductory Scratch workshop, hosted at a regional technology conference for teachers. After the 20 participants arrived, we showed them three or four projects created by young learners, to give them a sense of what might be possible to create with Scratch. Then, we transitioned to hands-on time for the teachers. The activity was Pass-It-On, in which the teachers collaboratively worked on a project connected to the theme of Halloween (which happened to be on the upcoming weekend). We started the activity by modeling – this enabled us to introduce the basic mechanisms of Scratch (e.g., snapping blocks together, running the program), giving participants what we hoped was enough scaffolding to get started. After the modeling, pairs of teachers had 15 minutes to start their stories. After 15 minutes elapsed, each pair stood up, left their computer, and moved to another computer, where they continued the story that they found at the new computer. After another 15 minutes, the pairs rotated again, and then eventually returned to their original computers to see how the other sets of partners had modified their initial creations. Participants were usually surprised and delighted by the evolution of the projects in their absence. (Although some people were sensitive about changes to their original vision.)

« 2 » We asked participants to talk about their experiences with the activity and how such an activity might work in their own classrooms. One teacher expressed doubt about adding the activity into her lessons. “This was great for me, but I couldn’t let my students get started this way. I’d need to show them more, right? I couldn’t just let them play, right?” She looked around the room at the other teachers for confirmation.

« 3 » A teacher on the other side of the room quickly jumped in:

“I don’t think you need to be so structured. I’ve been using Scratch for about three years. I started using the Scratch cards with kids because I thought that was a good way to introduce it to them. So I asked them to go through each of the twelve cards before they could start their own project. But that was a big mistake because they got very bored with those cards immediately. Today, what I do with the cards is that I leave them on the table and the kids know the cards are there. They can look for a particular card when they need it. The kids want to be able to just work on their projects and be a little freer.”

« 4 » Another teacher, sitting at the back of the room, forcefully raised her arm, while shaking her head:

“I teach it a different way – I don’t let them go and do it, because they just sit there and say, ‘I don’t know how to make the cat move!’ So, I lead them through Scratch step-by-step. It takes me three or four weeks to go through all that. Because if I just ask them to make something, some of the kids – some of them are creative and do produce something – but a lot of them just make something dancing on a screen saying, ‘Hi! Hi! Hi! Hi!’ Oh, you’re cool! Hi! Hi!”

Teacher attitudes and beliefs as context

« 5 » I was reminded of this experience as I read the responses from Hugh Gash and Thomas McCloughlin, Carina Girvan, and Giorgos Psycharis. All three responses raised important questions about the significance of context in supporting (or suppressing) constructionist approaches to learning in the classroom. In some cases, these questions focused on external factors – issues and constraints that individual teachers are subjected to as part of their lived contextual experience, but essentially beyond their control. For example, Girvan highlighted the constraining function that national assessments can exert on teachers experimenting with new pedagogical practices.

« 6 » Equally important, as the responses argued, a teacher’s own attitudes and beliefs play a critical role in directing and shaping their interest, willingness, and ability to include constructionist approaches to learning in the classroom. This is what reminded me of the workshop experience. These two teachers – who were contextually similar, subjected to the same geographic, socioeconomic, grade-level, subject-area, and policy factors – differed primarily in their attitudes and beliefs about their role as teacher and the role and capacities of their students, a type of “internal” context.

« 7 » Too often, professional learning experiences are designed around a facile compliance model – one in which teachers have an experience that they are then expected, without attention or sensitivity to contextual variations, to execute faithfully in the classroom (Lieberman & Pointer Mace 2008). In fact, there is significant complexity in translating professional learning experiences into practice as teachers negotiate external and internal contextual factors (Windschitl 2002). And, although both sets of factors are important, given the limited control that most teachers have over external factors, I argue that it is critically important to engage the internal contextual factors in teachers’ professional learning experiences.

« 8 » But what might this engagement look like? In the vision for professional learn-
ing that I described in my article, the teacher learns through experience, an approach aligned with similar endeavors described in the three OPCs and in the broader literature about teacher learning. In the specific case of ScratchEd, in which I study and support teacher professional learning as a means to support constructionism in the classroom, the teacher learning is itself constructionist, emphasizing learning activities of designing, personalizing, sharing, and reflecting. In this approach, the work of surfacing teacher attitudes and beliefs can cut across all four of these activities, but particularly in reflection. Reflection should invite teachers to consider their experiences within the professional learning setting, but, equally importantly, to engage in self-reflective processes, creating opportunities to consider their own preconceptions, attitudes, assumptions, and beliefs. Documentation can serve as a critical component of this self-reflective process – through personal journaling, interviews, or portfolios. These forms of documentation can trace the evolution of attitudes and beliefs over time, making the tacit explicit, and making change possible.

Acknowledgments


Received: 18 June 2015
Accepted: 26 June 2015

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Designing Constructionist E-Books
New Mediations for Creative Mathematical Thinking?

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Introduction: Infusing constructionism into e-books

Constructionism addresses the design for and the study of constructivist learning and, in particular, the process of generating meanings and expressing them through interacting with the structural affordances of artifacts, mainly digital artifacts. The artifact is at the center of attention in that the design for and the study of learning prioritizes the ways in which individuals or groups interact with and mediate artifacts. These artifacts thus play the role of key representational registers in, amongst other areas, language, scientific formalism and other kinds of representations. Constructionism has been perceived by many as an orienting framework or a framework for action within the context of design research, rather than a grand theory (diSessa & Cobb 2004). It has been characterized as an often provocative alternative or a novel reform-related approach to teaching and learning. And despite its initial characterizations as an individualistic approach, it has attributed significant emphasis to collaborative work and the development of shared meanings (Papert 1980; Kynigos 2012; Kafai & Burke 2014). This itinerary is in fact in line with the trajectory of constructivist perspectives, where the social dimension of meaning generation accrued a sharp focus in the past 20 years or so (Gash 2014).

This article is about designs to infuse constructionism into e-books so that they can afford creative mathematical thinking, i.e., to produce “c-books.” E-books appeared in a context that was not related to the questioning of educational paradigms or designing a new kind of interface or expressive medium. They adhered to the rationale behind large portals, to making resources available much more easily and cheaply to all, to making practical, temporal and locational issues insignificant with respect to access (Gardiner & Musto 2010). In education, e-book technologies soon became widely available for the writing and creation of e-books, examples of which are the i-book and Cabri-log, that allow the inclusion of “widgets” into the text. Widgets are objects other than text, usually videos but recently with some interactivity, as for example in the case of a quiz or a digital experiment simulator. Cabri-log extended the idea of widgets to allow for instances of Cabri exercises, games and tasks to be included amongst the text. It will undoubtedly soon become easy to include any kind of widget amongst text and make it public as a new kind of book.

But how can we think about a “Constructionist book,” i.e., a kind of e-book where a limitless variety of widget instances inviting social creativity and constructionist engagement are abundant and considered by “readers” as something natural. How does “reading” change? What roles do users of such books adopt and how does the way in which a “reader” is addressed change with respect to the text. Also, how is the meaning of a book going to change when it seems natural to use any “book” as a resource to shape and change into your own? How can the text address both narrative and the reader as actor?

Little effort has been put into understanding constructionism as an inherent property of learning in a variety of contexts and to looking for the constructionist element in tools, productions and educational milieus. Moreover, little effort has been made to forge connections between constructionism as a theoretical framework with other approaches to meaning generation and to designing courses and resources for constructionist activity. The implication has been that constructionism is perceived by the wider community as distinct, describing an exclusive kind of activity fragmented from others, thus maintaining a clarity and succinctness but at the same time address-
Orchestrating the process of design

Designing for students to engage in constructionist activities with digital media has not actually been democratized. It has, of course, been seen as a creative activity in itself. Not much attention has yet been given, though, to how it can be facilitated, inspired, fostered and generated. Designers of constructionist activities have often been addressed and perceived as idiosyncratic individuals. At the same time, however, the design of resources by professionals in education in general has increasingly been recognized and facilitated not only as an individual activity but as a social one in professional communities of practice (Pepin, Gueudet & Trouche 2013). So what would it take to make use of this dynamic and at the same time enhance the chances of creative designs aiming at a new kind of medium like the c-book? The strategy here was to inject diversity into the expertise of the members of designer communities.

Arguments elaborating the importance of integrated designs of constructionist artifacts by diverse actors are not new, both as an activity for creative designs to emerge (Kynigos 2007a) and as a professional development enhancer for teachers (Kynigos 2007b). In the “M C Squared” project, we drew from this experience by putting together four groups of designers with the task of producing c-books affording creative mathematical thinking. We orchestrated the syntheses of these groups so that they would act as hybrid communities consisting of actors with a diversity of expertise. We were particularly interested in composing each group so that there would be more chance to be creative and produce out-of-the-box but relevant ideas. To help us think and employ this strategy, we found Fischer’s “communities of interest” (CoI) to be directly relevant and useful. Such a community is organized and functions around a mutual interest and at the same time is made up of members representing diverse communities of practice and bringing diverse expertise and history to the group. The emergence of creativity in the design process was perceived as a system involving collectives (the CoI) designing with the c-book and characterized as cultures of participation (Fischer 2012).

In this context, design creativity was recognized as a multidimensional concept that can be identified in, among other situations, the processes or the outcomes of the design activity, or in the context within which such an activity is embedded (Gero 2010). The design of educational resources and instructional design in general has not actually been formally acknowledged and studied as a creative design discipline as compared to software design or architecture for instance. Only recently has creativity been acknowledged as a “built-in” dimension of educational resource design (Clinton & Hokanson 2012). The “social” component in various collectives of design professionals and its role in enhancing both individuals’ creativity and the creative capacity of the group in addressing complex design problems is also a relatively new focus of research. “Social creativity” actually explores the social and technical environment within which participatory design processes take place (Fischer 2012, 2013; Craft 2008) when specialists from different domains coordinate their efforts to achieve a common design goal. Social creativity arises from the synthesis and synergy of the different perspectives towards a complex design task of shared interest. Designing for digital educational resources for creative mathematical thinking (CMT) can therefore be viewed as a squared creativity challenge since it requires not only defining mathematical creativity but also situating the design process within a socio-technical environment that can boost educational designers’ creative potential. However, both challenges need some paradigm shifts in terms of thinking of, learning and designing pedagogical materials for mathematics (Chevallard 2015; Daskolia & Kynigos 2012).

An important feature of the technology developed in the project was meant for its authors, a feature supporting collective design of c-book units. Technically speaking, it provides an asynchronous tool for organized discussions allowing each designer to choose its representation between a threaded forum discussion and a mind-map view. Designers can switch from one to the other with a toggle button. They can attach and refer to widget instances, that reside in the c-book unit under construction. There are special semantics designed to
promote social creativity in the design process. Primary ideas – initiating discussions – are termed as “alternative,” and secondary ideas – continuing a discussion thread – are termed as “contributory” and “objecting." So each contributor has to state the nature of the contribution using the following options:

- **Alternative**: Expressing opinions, statements, arguments, initiating design process
- **Contributory**: Adding, cumulating, building on an existing alternative
- **Expressed by**: Questioning, refining, focusing/narrowing, expanding
- **Objecting**: Expressing objection to alternative, either by directly contradicting an idea, using disputational style, or by proposing another alternative
- **Off task**: Social interactions not associated with the task at hand: greetings, expression of humor, emoticons, phatic elements
- **Management**: Management of the progression of the task itself: planning what is to be discussed, who does what, if a problem is solved or not.

**Studying the process of design in a CoI**

To study, understand and usefully describe social creativity in the process of collective design of educational resources in a CoI we employed two theoretical constructs, “documentational genesis” (DG) and “boundary crossing” (BC). They were developed in different contexts and illuminate different aspects of collective designs (for a discussion of this approach see Ar-tigue & Mariotti 2014; Lagrange & Kynigos 2014). The former addresses the teacher as designer (Gueudet & Trouche 2012a). The latter addresses they ways in which digital artefacts can be used for collaborative design amongst professionals of diverse expertise.

DG was primarily developed as an approach to understanding teacher development and teaching activity in the classroom. The essence of the approach is that design, production, appropriation and versioning of resources is an integral part of the teaching profession and inherent in teachers’ working lives. Thus, if we study teachers through a lens prioritising their activities around their productions (documents) and the evolutions of these productions, we gain insights into both their teaching processes and their own development. Every teacher puts together a “valise” of resources and then continually renews, changes, adapts and reforms them as a result of using them in their classroom. Practices, beliefs, knowledge, reflections can thus be identified and studied through teachers’ activities with and uses of the resources in their own “valise.” Ghislaine Pepin, Birgit Gueudet and Luc Trouche (2013) extended the DG theory to study teacher development and ways in which the documentational approach can help structure teacher education courses and support in-service development. An important part of the approach is the integral use of instrumental theory (Rabardel 1995) by considering resources as artefacts that teachers use to create their own schemes of use (instrumentation) and make changes to so that they fit their personal pedagogy and teaching agendas (instrumentalization).

An important characteristic therefore of teacher activity is the continuous versioning of a resource. A technique to support teacher development is for teachers to keep a log of changes and rationale for these changes and then use it for reflection and discussion with others. In recent years, Pepin, Gueudet and Trouche have moved beyond addressing the single teacher and suggested that the documentational approach can work as a framework to structure teacher education courses where they share resources and jointly discuss and reflect on them within professional communities of practice. These resources adopt the role of living documents, i.e., ever-changing objects. The design rationales and knowledge behind decisions to generate and change resources can then be enhanced by teachers in the role of knowledge brokers, i.e., those who can convey that knowledge within the community by addressing diverse teachers.

Boundary crossing focused on explaining collaborative design and construction processes in collectives where diverse expertise was a necessity to meet a specific design and construction problem at hand. The essence here was to capture the processes by which members of a collective with very diverse expertise, language, assumptions and experiences engaged in a joint enterprise to build something (let us say an artefact) together that required the coordinated and joint employment of this expertise. The focus here was on the artefact and the role it played in helping the members of the collective gain some understandings of each other’s perspectives and enough knowledge to meet the high-stakes task of putting together a joint construction. The social aspect in BC is a foundational construct and the enterprise of jointly building a single artefact or construction is the main object of the approach. The artefact is at the centre of attention since its status is that it is continually being improved and argued over (it has been termed the “improvable object,” Bereiter & Scardamalia 2003; Kynigos 2012). Therefore boundary crossing is considered as both a challenge and a continual task at hand. Brokers are essential here since there is no time or agenda for each member to gain all the expertise of the others. Some joint meanings constructed and mediated by hybrid actors are therefore essential.

Boundary crossing was originally not meant to illuminate professional development or some kind of learning process in the designers, who were perceived as experts in their respective domain. However, the necessity to understand co-designers’ viewpoints, expertise and experience was in itself a challenge that required development of and the ability to change perspectives to cross the boundaries of the expertise of others. The process of developing skills, techniques and empirical knowledge on this issue was characterised by Sanne Akkerman and Arthur Bakker (2011) as containing four distinct learning mechanisms.
identification of the intersecting practices
coordination of both practices through establishing routinized exchanges to facilitate transitions
reflection leading to perspective-making and perspective taking
transformation that provokes changes in practices or even the creation of a new in-between practice.

We employed these two complementary constructs to evaluate the potential for the c-book technology to support and enhance the creativity of designers within the field of education. The prime agenda here was to enhance creativity in order to obtain an insight into the extent and potential for c-book technology to develop into a new genre of mediating resources for mathematics education and especially for CMT. Social creativity was seen as potentially more fruitful than individual creativity precisely because the fusion of diverse ideas would have more potential for the production of novelty in the medium. DG and BC therefore were suitable for studying and understanding collective design by Col working together to create joint constructions in the form of c-book units. DG provides an analytical lens to the perception of teachers as one type of designers within the education field, while BC allows us to gain understandings of the ideas as generated in collective design by Col members. Both approaches consider the role and essence of the artefacts jointly built within the Col and in that sense they can be characterised as constructionist. However, during the initial phases of the project it was felt that something more was needed to understand how such artefacts can be seen as eternally improvável and how the changes to them carry meanings and ideas, which the Col members cross boundaries to communicate.

Constructionism is a construct with a longer history than DG and BC and has been directly employed to discuss pedagogical design, especially looking at ways in which artefacts can be crafted to afford constructionist activity (Kynigos 2002; Healy & Kynigos 2010). It thus focuses both on professional design processes and learning processes focusing on the ways in which both of them are part and parcel of individual or collaborative bricolage or construction of digital artefacts (Kafai & Burke 2014). It illuminates how the rules behind the behaviour of digital objects and the fields in which they reside and the ways in which their representations can be manipulated can all constitute representational registers around which meanings are generated, shared and developed (Morgan & Kynigos 2014; Bartolini Bussi & Mariotti 2008). It thus provides an analytic lens for studying the design and construction process in close interaction with the changes made to the artefact in question and the meanings those changes carry. This has connections, of course, with the construct of “instrumentalization” from “instrumental theory,” but brings the meaning of specific artefact changes to the forefront (Kynigos & Psychiaris 2013). Constructionism thus provides analyses of c-book unit design processes with an emphasis on understanding the meanings generated through and with c-book changes. Equally, it provides analyses with an understanding of designs for affordances for constructionist learning by the c-book unit users since the widget instances within the c-books are often designed to afford constructionist activity rather than mere inquiry, exploration or response to questions.

**Col discussions and products**

The “Windmills” group

The first Col was given a general theme for writing a c-book unit of “windmills.” This was meant by the researchers to be a spark for social creativity and an invitation to think out of the box. The Col included designers and teachers in mathematics education, computer science and engineering/vocational training. Three of the teachers were also experienced developers. A total of 75 contributions were posted to ColCode (the c-book author collaboration tool) during the initiation phase of the Col and its first work cycle. A number of these were related to technical issues identified and reported by the members (eight posts). Another eight posts were related to organisational issues, such as deadlines, division of work, etc., and there are also four off-topic contributions. The rest of the posts (55) either started a discussion (initiating – alternative ideas) or continued an existing thread (contributory or objecting ideas). The group had been discussing how to create a c-book unit on windmills that would foster mathematical creativity for students. The discussions had taken place in two distinct phases. During the first, the Col members mainly focused on trying out the affordances of the widgets, which could be embedded in the c-book at the time. They carried amongst them experience with using “Geogebra” to develop simulations and models embedding mathematical rules. “E-slate Turtles!” was also used to create parametric computer programs for “half-baked” figures, asking the reader to fix them. The tool itself is a Logo-based Turtle Geometry environment with tools to change the value of variables dynamically and observe the resulting DGS-like effect on the corresponding figure (Kynigos 2007a). The Col members used these widgets as “factories” or “kits” to create “widget instances” meant for the “reader,” so as to test their initial ideas about the shape, rotation and productivity ratio of different sails of a windmill. These instances were shared with the rest of the group through ColCode, making them available for comments and modifications by the rest of the Col participants. During this process, the Col members started posing design issues regarding the instances and the activities proposed.

Two design options came out as the most dominant ones at the beginning. The first one started from designing an instance that would offer students an already created shape for representing one sail and its frame. The students would use this shape as a basis for constructing the whole (polar) array of the sails. The other option related to designing a more elaborated instance that would call for some kind of “deconstruction.” These two options were reconciled as the Col members suggested giving students “half-baked instances” (see Kynigos 2007a) that would invite both constructions and deconstructions. After proposing a set of ideas for half-baked instances, the Col members went one step further. They suggested giving students the opportunity to create their own windmills using the available tools and resources, allowing in this
way the fostering of “unexpected” ideas that would surprise even the designers of the instance. The new issue that came around and had not been addressed so far in this discussion was how to create a “spark” that would not give away too much, but would at the same time provide the available resources for igniting students’ mathematical creativity.

A critical episode

19 A few weeks after this first phase of their discussions, and having gathered and revised a set of instances, the CoI members started to change their focus. They expressed the need to start creating versions of a c-book unit instead of just producing instances. This was a first indication that they viewed the c-book as a “document,” as new technology integrating both instances and some kind of activity flow for students to use.

20 In this new phase of their discussions, the main issues raised concerned:

1. the age of the students to which this c-book unit would be given;
2. the school’s official curriculum and whether the c-book’s activities should have any connection with it;
3. the order in which the selected instances should appear in the c-book’s pages in relation to their affordances;
4. the distribution of mathematical notions among the pages of the c-book unit moving from simpler to more complicated; and
5. the narrative to be added to the widgets that would be addressed to the students working with the c-book unit.

22 This discussion thread started with Mary posting the minutes from a Skype discussion between herself, Sue and Ginger on how to structure the available instances inside the unit. Sue, who had also talked to George and Sandy, gathered contributions from all the others and suggested using Turtleworld instances for the first three to four pages, then Geogebra instances from the fifth or sixth page, and Turtleworlds again at the end. Apart from this specific structure, she asked everyone to work towards turning these instances into “didactical scenarios,” i.e., to include narrative for the reader. This was the first attempt in the CoI to relate the instances produced to some kind of text that should accompany them. Sue, an experienced math teacher, talking to other (mostly mathematics) teachers in their language, using the word “didactical” to outline what this text should be about. Saying nothing more about the text, Ginger suggested going step by step with the Turtleworlds instances in relation to the mathematics to be embedded. Viewing all instances as part of a larger picture, she also proposed having a closing activity for exploration, with instances from both Turtleworlds and Geogebra. At that point, the age/grade of the students to work with the c-book unit and their math textbook rationale became a point of controversy, and the CoICode posts started to contain comments in which the c-book unit’s structure was intertwined with these matters. Kate went back to a previous post in another tree (see Figure 1) and mentioned the idea of having activities that would be more demanding and complicated as the students moved on along the pages of the c-book unit. That design would ensure having a c-book unit that did not only refer to specific ages, but at the same time kept a broad windmill theme and had sets of activities with the same characteristics. This discussion closed as Sue, with a more pragmatic view, pointed out that integrating the instances in the c-book unit should be the first step and the rest should be decided afterwards. Adding or removing elements from the design of the activities would do the trick, making the c-book suitable for different ages. Mary agreed with Sue and advocated adding descriptions for each of the instances, which eventually could lead to breaking down an instance into more pages, making it suitable for Junior or High School students. Along the same lines, George made explicit that he viewed every

Figure 1 • Excerpt from the CoI’s discussion thread.

http://www.univie.ac.at/constructivism/journal/10/3/305.kynigos
activity as an integral part of the c-book unit, not to be formed independently of the rest of the c-book unit. Again, this CoI seemed to view the c-book unit as a whole, as something with a specific theme, and a series of activities with common characteristics that could change to suit different ages. Here is an excerpt from a CoICode contribution.

"Let me go back to this: I think it doesn’t matter to decide precisely when we will use Turtleworlds or Geogebra. The instance will change as soon as we start writing the text. I believe the text and the instance are one unit, one c-book unit and not two pieces. The widget can’t be alone. So I think that maybe we shouldn’t think of the instance but of the c-book unit as a whole thing." (George, 30 April 2014).

To this end, Mary suggested the first wording of the activities, in this case: “Build your own windmill” for the last activity of the c-book unit, which was meant to be the one in which students could freely create a windmill. This was Kate’s idea, influenced by a comment made earlier in the discussions by John, who noted that without an intervention, the students could use their imagination to be more creative.

"So, this CoI was obviously bringing experiences with fragmented technologies to the table, either focusing on standalone instances to be changed and experimented with by the students, or focusing on the thread of the narrative of the unit and the pacing of the mathematics, the difficulty and the level of openness of the activities. Looking at this through the lens of the DG approach, we can see the teacher designers’ perceptions of the enterprise as the c-book being a kind of a joint “valise” of resources, which were the instances. It was not obvious from the beginning that the task was to think differently of the medium. On the other hand, the not-teacher designer members could not easily bring scope and sequence in the discussion. Communication started by means of discussing suggested instances then engaging in changing them to portray diverse views, such as “find the bug and then build your own windmill” (see Figure 2). We already witnessed a jolt in their own thinking when their discussions progressively took on more angles to the enterprise. How could the c-book include an engineering and a coding element, and integrate them with mathematical concepts? How could it allow for and promote unpredictable student activity and personalized creative constructions with the instances? How could it inspire such activity through the accompanying narrative? How could it embed diverse mathematical ideas organized in ways not found in standard curricula? And most importantly, how could the designers think of the c-book as a new medium instead of a traditional sequence of exercises, each with its own widget instance?

The following sub-section involved a more diverse CoI and the integration of two more diverse domains, mathematics and environmental issues.

The “Cycling in the city” group

The “Cycling in the city” CoI included teachers and researchers from mathematics as well as environmental education, three of which were also experienced developers. The researchers set the task for the group to build a unit on “Cycling in the city.” A total of 82 contributions were posted on CoICode in about a month and a half. As with the windmill CoI, a number of these were related to technical issues identified and reported by the members (12 posts). Another 10 posts were related to organisational issues, such as deadlines, division of work, etc. The rest of the posts (60) either started a discussion (including initiating or alternative ideas) or continued an existing thread with contributory or objecting ideas. During the first month, the group progressed from an initial phase of brainstorming to a more integrative phase of synthesis. The first phase was characterised by the experienced members’ anxiety to show previous work, i.e., instances they had already developed for other purposes and contexts. The more inexperienced members seemed to be grappling with a significant cogni-
tive load and with the challenges of using a completely new digital environment as their main working environment. An important tension emerged from the outset between environmental education and mathematics teachers on the one hand, and secondary and primary education teachers on the other. This tension became evident in a vivid discussion by the CoI about the target age-group, and in many encounters on the appropriateness of specific mathematical concepts for young pupils. Another output of this phase was the plethora of posted ideas and supporting materials (a total of eight ideas, supported by 14 instances/digital materials), and the tendency to open new threads to post new ideas rather than build on already posted materials. The second phase indicated progress towards synthesis, as the deadline for the c-book unit delivery was looming. The experienced members now seemed more willing to comment on others’ ideas, whilst the more inexperienced became more inquisitive and courageous enough to ask questions and propose synthetic solutions. The analysis of the data revealed several foci of interest while they were collaboratively thinking of, discussing and co-working on the design of their c-book unit.

A critical episode

“27” One of the first ideas put forth in the CoI came from a female member, Anne, a young developer. She described the idea not in the abstract but by attaching an E-Slate instance of a game model she had developed on another occasion. This instance was based on the idea of a GPS and a distance meter device that could be manipulated by students to move a vehicle in the streets of a city. Anne suggested an adaptation of this initial idea that replaced the car with a bike. The fact that Anne’s idea became public and inspectable through the posting of her “MyGPS” instance almost immediately triggered a new idea by Sara. It was built on Anne’s but extended it. It originated from an experience Sara had had with her students, who faced difficulties in understanding how to chart an itinerary in more traditional approaches:

“…Could we have arrow icons, which the children could put on the itinerary they are given in order to mark it?” Now, I’m sure this is not clear, but I have something in my mind from the first grade school book. My pupils had difficulty understanding this on paper. I’ll find it and post it.”

(Sara, 30 March 2014)

“28” However, this new idea was received by Anne with reservations, both in terms of feasibility and substance: “Does it really add something new not covered by the original instance?” she asked, questioning the novelty of Anne’s suggestion. She went on further buttressing her argument with the attachment of a new version of the instance and by asking Sara to try it. The new instance resulted from an adaptation Anne had made to the original MyGPS instance to the bike theme:

“…I think I get what you mean, but I don’t know if this is feasible. Anyway, in this microworld, on the ‘driving control’ utility, they can see with arrows and letters (N, S, E, W) the direction of the bike in space. I’m attaching the same microworld, this time with a bike instead of a car. Try to play with it and tell me if it can be adjusted to the ages we are discussing (primary school).”

(Anne, 9 April 2014)

“29” A second extension of Anne’s initial idea was suggested by Sharon, who introduced different levels of difficulty to make the task suitable for younger ages. The idea was then further developed in more detail to specify particular features to be added in the microworld:

“…Anne, I also like this microworld and I think it can be easily adjusted for smaller ages. For sixth grade, I would suggest that each destination go through three phases: free navigation, where they just go to the target destination; reaching the target destination with as few movements as possible, as they are recorded on trip logs; and finally program the route for the target destination in Logo, using the existing itinerary example on the Logo component (it could be considered as a ‘half-baked’ microworld).”

(Sharon, 10 April 2014)

“30” At this point, another CoI member, Suzan, a high school math teacher, intervened. She acted as a boundary broker in the CoI, as she was the one who insightfully pinpointed the common threads between different lines of thought within the CoI on a regular basis or proposed creative syntheses of them. On this occasion, Suzan identified the commonalities between an instance suggested by another CoI member (Tom) and one proposed by Sara, who suggested including a compass for orientation. She proposed this as an extension of Anne’s initial instance.

“…Could we achieve a synthesis of ‘Orientiation in the city’ Tom made, and the compass idea? So that the children move with a specific orientation?”

(Hilary, 23 April 2014)

“31” Suzan’s suggestion was taken by a fifth CoI member (Hilary), a primary teacher with a specialization in environmental education, who identified the challenge of combining the two ideas and further developing each idea through the other:

“Playing, though, with myGPS again, I don’t think I achieved something new with GGB. MyGPS, as Anne said, also has a compass, it allows selection of length (with different metric units) and sends players to different destinations, on which, once reached, players get positive feedback.”

(Suzan, 28 April 2014)

“32” Suzan responded to the challenge actively by creatively designing a new instance with a different widget, Geobebra 4.0, which substantiated the idea of “compass.” However, although it was approved with much enthusiasm by Sara, it was finally rejected by Suzan herself as not adding anything actually new or different (criterion: novelty) compared to the “MyGPS” instance:

“…Could we have a look at Tom’s widget, ‘Orientation in the city’? I think it’s very close to what you’re looking for.”

(Suzan, 23 April 2014)

“33” This episode would be impossible to read if we did not have a means to interpret the role of the many instances suggested and changed. Anne’s independence from the curriculum, the sequence or the age group made it difficult for her to understand the validity of Sara’s suggestions. Sara, on the other hand, could not easily see what was changeable in the instance suggested by Anne and what was not. The
Discussion addressed a large number of issues simultaneously and was thus difficult at the beginning. The mutual reflection that led to perspective taking, however, did progress to members transforming their own thinking and approach to agree on the instance in question. This would have not been possible without the members with expertise outside mathematics education.

Conclusion

Making it technically possible to infuse a constructionist element into e-books may impact educational practices by placing constructionism on the map of wide-scale designs for school resources with a genuinely integrated role. C-books can potentially develop into a new kind of mediation in educational practice. The argument here is that to enhance the chances of this happening, the design of c-books needs to be orchestrated and supported as a socio-technical environment inviting social creativity in communities of diverse professionals with an interest in education. Socio-technical environments are inherently constructionist in that designers engage in creating, exchanging, re-mixing and tinkering with constituent artifacts in the process of generating a c-book. More work is needed to understand this process of collective design and to develop methods to support it.

C-books may potentially change the role of the “reader” and the ways in which a book addresses its user. We can imagine a c-book unit containing a variety of instances including Scratch remixes, NetLogo simulations and E-slate games, all designed to generate a coherent theme within which users can read, look for connections, remix dynamic content and turn the unit to something of their own, a living document as Gueudet & Trouche (2012a) would say. What we were witnessing when the article was written were the emergent collaborative design processes of a small community of diverse actors, some from outside mathematics, some of whom were experienced constructionist designers and others experienced teachers in ordinary schools. The technology at hand enabled them to base their designs on the idea of integrating two very different media, conventional books and conventional constructionist widget instances.

The integration of these kinds of media, however, was something we had only begun to observe. Different levels of creative design processes were recorded in the activities of the two CoI, addressing, among other matters, the design of a widget instance, pedagogical design in general, the design of a narrative to describe a learning scenario that turns the instance into a learning resource. It is rather unlikely that the CoI would get into addressing all these different foci and levels of design if it were not necessary to think and work simultaneously along all these lines during the design of the c-book unit.

The “MyGPS” story shows how the social character of the creative process in the CoI is manifested through the mediaization of ideas and artefacts that are perceived to be under construction and improvement. They are deployed within the CoI in the sense that they pass from one CoI member to the other as boundary objects are approved or abandoned, qualitatively developed or changed, or different ideas and artefacts are given birth to. Moreover, each idea, creative or not, seems to be conceived or built based on a pre-existing reference point. Tangible inspectable and malleable reference points such as the “MyGPS” artifact facilitate focus on and emergence of creative ideas. In the CoI activity, the role of a reference point is eventually played by the consecutive versions of the c-book unit. This leads us to consider any idea put forth in the course of the CoI design process of the c-book unit as potentially useful for creating the next c-book version. C-book unit versions themselves acted as higher-order boundary object resources for the CoI members to use to scaffold and anchor their creative thinking and design performance (Kynigos & Kalogerla 2012). Ideas and c-book unit versions seemed so interlinked that CoI members could not refer to an idea or suggest any alternative to it without explicitly or implicitly connecting

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it to a unit version. This is typical of a socio-technical environment in the way outlined by Gerhard Fischer (2013). The borders between any design idea and its reification to a c-book unit are practically blurred. In that sense, c-book units and their structural affordances operated as expressions of design ideas amongst the CoI just as constructionist media have been described to work for learners. The CoI members seemed to use various criteria in approving or rejecting an idea. Prominent among them was the criteria of appropriateness, be it pedagogical, strategic or domain-specific. Nevertheless, more criteria were employed, such as novelty and usability. In early stages of the CoI performance, ideas that were not accompanied by an active attempt on the part of their initiator to put them into use were usually abandoned. Even when they were meant to be put into use, the initiator had to be quite explicit about what they actually suggested in order to push forth their idea. This was better accomplished if they turned their idea into a digital artifact or suggested their idea through instrumentalization, by means of making a respective change in an existing artifact. So, in retrospect, employing constructionism with DG and BC in conjunction was necessary for us to study the significance and potential impact of what was going on in the CoI.

The use of these frame provided us with tools to understand the teacher as a perpetual resource designer and the significance of boundary crossings with other professionals to generate creative ideas in a socio-technical environment. Constructionism was of course a necessary theoretical lens but not sufficient fully to understand collaborative designs in these particular types of community. This approach may enhance the usability and relevance of constructionism as a framework for action both for resource design and for learning with the use of c-books. These were the first considerations of infusing constructionism and creativity into widely recognized educational media, inviting the democratization of designing for constructionist e-books. No doubt, the future will tell how and if these technological affordances will merge and how constructionist activity will play out with their uses.

Received: 21 February 2015
Accepted: 17 June 2015

Open Peer Commentaries on Chronis Kynigos’s “Designing Constructionist E-Books”

Objects To Think With
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> Upshot • Chronis Kynigos’s article invites us to explore how to make familiar objects for learning — namely, books — more constructionist. In my response, I ask questions about the affordances and potential limitations of books as central objects, particularly about the role of the learner in relation to the objects.

What does “book” evoke?

> 1 « The notion of the “object” occupies a central role in constructionism. Objects serve as physical representations of and supports for learners’ internal cognitive constructions, which can be manipulated, deconstructed, and reconstructed as a means for negotiating and extending ideas and understandings. In describing the special role of objects in constructionist approaches to learning, Seymour Papert related his own childhood experiences, in which gears served as powerful “objects-to-think-with.” His experiences with gears provided the impetus for designing (and encouraging others to design) “objects-to-think-with” for children. He argued that such objects should be things that children can “make theirs for themselves and in their own ways,” serving as “an intersection of cultural presence, embedded knowledge, and the possibility for personal identification” (Papert 1980: 11).

> 2 « In his target article, Chronis Kynigos explored how a particular type of object — books, and more specifically e-books — could be made more constructionist (constructionist e-books, or e-books). The article focused primarily on the development process for these constructionist books. In my response, I have opted to focus on a more basic question about the object itself: Are “books” interesting objects for supporting constructionism? To explore this question, I consider three related questions:

• What does “book” evoke?
• How does “book” align with a constructionist worldview, particularly from the perspective of personal connection?
• Whose “book” is it?

> 3 « The objects we choose as our things to think with shape our experiences in important ways, both through their physical properties and their conceptual power. As George Lakoff and Mark Johnson argued, “concepts structure what we perceive, how we get around in the world, and how we relate to other people” (Lakoff & Johnson 1980: 3). Objects can enable thinking and action, but equally, and potentially more problematically, they can limit us by “keep[ing] us from focusing on other aspects of the concept that are inconsistent” with the reference...
Constructivism does not inherently reject that all instruction is bad” (Kafai 2006: 36). The reaction of some constructionists has been an ongoing discussion in educational research (e.g., Craig 1956; Anthony 1973; Perkins 1991), particularly in the context of design (which focused on play through game creation, peer-driven and playful construction might affordances of the “book” and the role of expertises within communities) and Kafai’s (1995) and Idit Harel’s (Harel & Papert 1990) LOGO research and design activities (which focused on peer, cooperative strategies for building knowledge and expertise within a community) and Kafai’s (1995) and Idit Harel’s (Harel & Papert 1990) LOGO research and design activities (which focused on play through game creation as an entry point for learning).

In this particular example of c-books, which focuses on mathematics content, one significant barrier to engaging children as designers and co-authors of the c-book is their lack of mathematical domain expertise. Prior work might suggest strategies for responding to their novice expertise, such as Marlene Scardamalia and Carl Bereiter’s (1991) CSILE research and design activities (which focused on peer, cooperative strategies for building knowledge and expertise within a community) and Kafai’s (1995) and Idit Harel’s (Harel & Papert 1990) LOGO research and design activities (which focused on play through game creation as an entry point for learning).

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Received: 16 May 2015
Accepted: 17 June 2015

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How does “book” align with a constructionist worldview?

Electronic books (e-books) have the capacity to extend the potential of books as a communicative medium, disrupting the linear, individual, and static expectations of books. Linking mechanisms and adaptive systems potentially make it easier to engage in non-linear book experiences. Social mechanisms, such as public highlighting of texts and visible commenting, make the book experience less isolated. Embeddable dynamic computational content can extend books beyond static text and images. But despite these new modes and forms of navigation, interaction, and content, e-books are still primarily didactic artifacts, structures developed by an expert and presented to a novice. What role can this type of didactic object occupy in a constructionist learning environment? How might the object itself, as the authors explored in the article, be reconceptualized to be more constructionist?

In the case of the c-book, we should “keep it in check” by critically examining how the object might support or inhibit learning, from a constructionist perspective. The article presented the c-book as an object that learners can engage “as a resource to shape and change into [their] own” through interactive widgets, which aligns with the constructionist aspiration that learners should have access to objects they can identify with personally. But the complexities of enacting this personal connection between the individual learner and the c-book are noted in several places in the article.

One complexity was the difficulty in creating a unified artifact that offered a suitable level of structure for different age groups. For example, both design groups struggled with how to make their c-book text and widgets accessible to learners of diverse ages: mathematical content that might be accessible to an older student might be beyond the capacities of a younger student, while content that might be appropriate for a younger student might be insufficiently engaging for an older student. Another complexity was the difficulty in providing sufficient freedom to encourage creative engagement. The design groups struggled with balancing structure and freedom in the activities in a way that created space for learner creativity. The didactic text and widgets of the c-book constrained opportunities for learners to shape the book, and the designers searched for mechanisms for the “reader” to reconstruct/deconstruct, such as the “half-baked instances.”

But perhaps the most striking tension between book as didactic object and the aspirations of the c-book as constructionist artifact emerged through the article’s presentation of the design process. It was quite evident that c-books provided a constructionist experience – as a collaborative and creative process for the designers. As I was reading about the creative work undertaken by the design group participants, I wondered how their processes with the c-book as object-to-think-with, rather than c-book as product, could be made available to young learners.

In this particular example of c-books, which focuses on mathematics content, one significant barrier to engaging children as designers and co-authors of the c-book is their lack of mathematical domain expertise. Prior work might suggest strategies for responding to their novice expertise, such as Marlene Scardamalia and Carl Bereiter’s (1991) CSILE research and design activities (which focused on peer, cooperative strategies for building knowledge and expertise within a community) and Kafai’s (1995) and Idit Harel’s (Harel & Papert 1990) LOGO research and design activities (which focused on play through game creation as an entry point for learning).

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Karen Brennan is an assistant professor at Harvard University in the Graduate School of Education. Her research is primarily concerned with the ways in which learning environments can be designed to support young people’s development as computational creators.
In his target article, Chronis Kynigos describes first steps in the design of what he and colleagues call "c-books" – e-books with embedded constructionist "widgets" that allow readers to interact with and create their own examples of mathematical phenomena. These books, Kynigos suggests, offer an opportunity for the constructionist community to extend beyond our current niche and to inform the broader educational enterprise. To explore how constructionism could both infuse and transform the existing educational milieu, diverse collaborative groups ("communities of interest," or CoI) including designers, educators, and other professionals were assembled to envision c-book units that challenged conventional notions of mathematical creativity.

I was excited to read Kynigos's detailed analysis of the CoI's design processes. Systemic accounts of design – in particular, early ideation among collaborative groups – are rare. This analysis identified specific moments and tensions that were productive in the advancement of groups’ designs, and traced the trajectories of designers as they worked across disciplinary boundaries. One key finding of the work was that ideas that were "put into use" ($37) were more likely to be pursued and refined by a CoI. Another was that designers came to understand c-books as living documents that were "eternally improvable" ($15). The article lends new insight into how we can foster successful collaborative constructionist design, lending a voice to the very professionals we rely on to connect to actual classrooms, learners, and the educational enterprise.

However, I was left wondering where one very critical element – the learner or reader of c-books – was located within this suggested ecology of collaborative constructionist design. In the article's guiding questions, the reader is clearly at the center: "How can we design a resource that addresses a reader who can use the same resource to tinker and construct with it?" and "How can we foster creativity in the design and writing of c-books aiming to engage 'readers' in creative constructionist activity for mathematical thinking?" However, readers were not part of the design teams. They were not specified in the design tasks given to the CoI. And designers' attention to readers as learners was not an explicit focus of analysis.

At the same time, it seems questions and tensions about readers are what drove the CoI to make progress. In the "Windmills" case, the critical episode that led teachers to consider the c-book as a "valise" of resources rather than a static artifact ($24) emerged from concerns about how to engage readers of different ages and preparation levels. In the "Cycling in the City" case, new versions of the MyGPS tool were inspired by Sara and Sharon’s concerns about their own students as potential readers. In both cases, these tensions emerged organically after some time, as CoI worked themselves to specify readers of c-books. Those tensions and specifications prompted development of multiple versions of the c-book unit, which subsequently propelled each group forward as they thought about the flexibility and novelty of c-books as a medium. Still, these spates of progress were inspired by discussions that focused on somewhat superficial characteristics of readers such as age, preparation, or developmental level.

What would it look like to center readers more explicitly and more deeply in the design of c-books at these early stages? Here, I make a few proposals, and consider how such re-centering might further increase the chances for creativity and feasibility in the resulting products.

There is a tradition of involving youth as designers of technology in the constructionist community (Harel & Papert 1990; Kafai, Ching & Marshall 1997). Often, this work focuses on what students learn from design experiences. However, young people are adept at using technology-mediated tools, and are likely to bring new perspectives designers might not expect. Allison Druin (2002) describes ways to involve youth not only as users or testers but as informants or co-designers of technology. Involving readers early on as members of a CoI is feasible and likely to introduce new, creative, and youth-accessible solutions to c-book design problems.

In the cases presented, questions about readers’ age and curricular experiences helped provide CoI with traction in creating multiple, flexible designs. But even learners of the same age and educational experience exhibit diversity and dynamics in how they approach a task. Teacher educators have found that engaging with student work can help teachers focus on student thinking and learning, and to develop appropriate instructional trajectories (Kazemi & Franke 2004). Similarly, reviewing video or examples of student work can bring together researchers, designers, and teachers to integrate different perspectives (Sherin 2003). Just as putting ideas to use can help designers make progress, seeing ideas in use can shed light on what novel creative pursuits can be enabled in using c-books.

Youth, families, and classroom communities already engage in a variety of creative practices that can serve as bridges to technology-rich explorations emerging within c-books. Readers sketch, tell stories, play games, and craft with classroom materials – these all feed into and inform their experiences with technology. Building on readers’ existing knowledge and practices can promote creativity, engagement, and interactions with one another using new media (Lee 2003; Horn 2014). For example, learners quickly appropriate tools that fuse programming with pre-existing creative and
play activities such as wooden block toys (Bers & Horn 2010) to create fundamentally new technological experiences. Logo itself was built upon learners’ embodied experience of movement in the world (Papert 1980). Exploring such connections explicitly can re-center student activity and establish better connections between c-books and the broader pedagogical agenda.

« 9 » The careful, well-documented collaborative design of c-books is a promising way for constructionism to enter the broader educational conversation. Involving readers themselves as part of this design ecology, however, is critical. In the end, measures of successful design and design learning lie with the readers: materials are eternally improvable because readers are ever changing, and readers are ultimately the ones who will make sure materials are put to good use.

Michelle Wilkerson-Jerde is an Assistant Professor of Education in the School of Arts and Sciences at Tufts University. She designs and studies expressive technologies—tools that bridge practices familiar to youth such as sketching, storytelling, and animation with computationally-rich practices such as simulation and data visualization. Her current projects include SIMSAM (with Brian Gravel), an integrated animation, simulation, and measurement toolkit, and DataSketch, a tool to create programmable data visualizations using digital ink.

Thoughts on Developing Theory in Designing C-Books
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> Upshot - As a mathematics teacher educator and “digital tourist,” I focus my response to the many questions posed by Kynigos from three perspectives. First, I outline the theories he uses to frame the reporting of the research into the design of constructionist e-books. Second, I compare his theoretical tools with design-based research as an organising framework for a research project of this nature. Third, I propose the possible contribution of further theory-testing to the work.

Possibilities for constructionist e-books

« 1 » Chronis Kynigos introduces two theoretical constructs that he found useful in researching the “participatory design processes” that the creation of c-books units requires. These are “documentational genesis” (DG; Gueudet & Trouche 2012b) and “boundary crossing” (BC). DG theory encompasses two closely related processes:
• instrumentation: in which features of a resource or resources influence a teacher’s practice and the knowledge the teacher develops through using the resource(s); and
• instrumentalization: in which the teacher’s expertise guides choices between different resources and how they are modified and used.

Extensions of and adaptations of DG theory have been discussed by Birgit Pepin, Ghislaine Gueudet and Luc Trouche (2013) to encompass a technique for structuring teacher education courses where teachers share resources and jointly discuss and develop them within professional communities of practice (Kiernan, Tanguay & Solares 2012). This augmented DG theory frames the iterative nature of the research, both retrospectively in examining what has happened in the four communities of interest (CoI) on which Kynigos reports and prospectively as an imagined future in the hands of teachers and students as “readers” of the c-books as designed. Unless the construction of the c-book is an end in itself, there may be need for a further robust “framework which seeks to describe the salient features and relationships between relevant concepts to describe a phenomenon, but making no claims about it” (da Ponte 2013: 319).

Design-based research (DBR)

« 2 » Although the research project reported here does not identify itself as design-based research, it appears to exhibit most of the characteristics of such research (Anderson & Shattuck 2012):
• being situated in an actual educational context;
• focusing on the design and testing of a significant intervention;
• using mixed methods;
• involving multiple iterations;
• involving a collaborative partnership between researchers and practitioners; and
• evolution of design principles.

An earlier account of the “crosscutting features” of DBR places theory-building and theory-testing at the heart of the project, giving DRB “an intermediate theoretical scope” and describing such theories as “humble” as opposed to “grand” (Cobb et al. 2003). Constructionism might be classed as a grand theory and the project might benefit from the development of further more “humble” theories in the testing of repeated iterations of the work in the educational settings at which they are aimed.

« 3 » The first and most compelling argument for initiating design research stems from the desire to increase the relevance of research for educational policy and practice (van den Akker et al. 2006). While there are huge pedagogical challenges inherent in the c-book research project, which aims to foster innovative technology-based mathematical creativity that can be translated into “a new kind of mediation in educational practice” (Kynigos), the generation of increasingly fine-grain theories of learning would increase the usefulness of the research by linking the creation, design, function(s) and goal(s) of the c-textbooks.

Conclusion

« 4 » The outlines of critical episodes in relation to the “Windmills” and the “Cycling in the City” groups both appear to pivot around issues of purpose and applications to teaching. The case is strongly made for a wealth of possibilities for the development of CMT and for mathematics teacher development in the diversity of expertise among participants. Kynigos draws on “boundary crossing” as a theoretical construct to describe participation in the socio-technical environment comprising “communities of diverse professionals with an interest in education.” Etienne Wenger (1998) conceives of boundary crossing as “brokering,” a job that he regards as “complex.” He also attests to...
the “politics of participation and reification” and the notion of “economies of meaning.” Such constructs might usefully be employed to investigate how a greater focus on learning outcomes for students might “afford” the emergence of new and innovative learning goals, both broad and open-ended.

Chronis Kynigos expresses a further need to test the widget instances, the pedagogical design in general, the design of narrative to describe the learning activity and the design of the overall scenario for the c-book unit on actual students in educational settings, both actual and virtual. With greater attention to explicit theory building, the findings will be constructionist, creative and of considerable use to the mathematics education community.

Author’s Response:
Designing for New Mediations: A Constructionist Approach
Chronis Kynigos

> Upshot • The three commentaries focus on the c-book as “object,” on locating the learner in the design process and on the challenge to develop more fine-grained theory for constructionist collaborative design of educational resources. I respond to this delightfully critical discussion in three ways, addressing the c-book as a potentially new kind of mediation, thinking of constructionist collaborative designs as creativity enhancers and considering constructionism as one of the key frameworks for understanding collective designs.

I found the three commentaries to be delightfully critical and evocative in a complementary yet cohesive way. Karen Brennan focuses on how we can perceive of the c-book as a constructionist object, i.e., an object to express and communicate meaning and to think with. Michelle Hoda Wilkerson-Jerde very poignantly raises the need to locate the learner both in the use of the c-book and in the process of collaborative design of a c-book. Dolores Corcoran, on the other hand, focuses on the process of collaborative design and encourages a further development of fine-grained theory to orchestrate and to study such processes.

I will structure my response in three main parts: on the growing importance of the role of digital objects as meaning mediations (Bartolini-Busi & Mariotti 2008), on the consideration of constructionist collaborative designs as social creativity enhancers (see Fischer 2013) and on the strategic importance of constructionism to “enter the broader educational discourse and landscape” as Wilkerson-Jerde aptly puts it (§9; see also Artigue & Mariotti 2014). I see my target article as making a necessary affordance of the medium. The “reader” of a c-book may do unpredictable things with it by making changes to the dynamic widgets within. These changes are expressions of meaning; the whole c-book becomes a frame within which meaning can be expressed, generated and made visible. This poses challenging questions for future research. How will the notion of “author” change? What kinds of information structure may enrich the potential for meaning generation and what kind of guidance may encourage meaning generation now that simple information or rigid instruction are not the only affordances of the book medium?

The c-book as object and as mediation
Dolores Corcoran rightly points out that the “educational book” is a mediation object loaded with assumptions regarding the role of information and its transition from producer to consumer, and the prevailing importance of structure and some kind of inherent intent that the author has towards the reader. Consider, however, the notion of “book” as an evolving artifact for mediation of meanings. The evolution from books to e-books allowed the production of new kinds of objects where information that is linear, static and addressed to individual consumption is seen as a restriction they are now free of. This is already bringing a change to the book as an informational medium. Now consider c-books, where structure, intention and guidance, as well as the transfer of information, are now an option and not a necessary affordance of the medium. The “reader” of a c-book may do unpredictable things with it by making changes to the dynamic widgets within. These changes are expressions of meaning; the whole c-book becomes a frame within which meaning can be expressed, generated and made visible. This poses challenging questions for future research. How will the notion of “author” change? What kinds of information structure may enrich the potential for meaning generation and what kind of guidance may encourage meaning generation now that simple information or rigid instruction are not the only affordances of the book medium?

The c-book may bring significant change to books and e-books, inviting much more directly the generation of meanings through constructionist activity. C-books can now afford diverse but dynamically linked representations, can take the role of a fallible, improvable, malleable artifact, a medium with which to express and communicate ideas. At the same time a c-book can mesh this kind of activity with contextualizing narrative affording, for example, the description of a system where meanings are
Interrelated in situations involving human activity and relations.

Constructivism has grappled with the problem of how to think of meaning generation as individually experienced and as emerging in interactionist social settings (Riegler & Steffe 2014). Constructivism zooms in on the notion and the importance of the use of artifacts as expressions and mediations of meaning.

With book technologies, the book and the widget are challenged. Meshing the two kinds of media does not simply mean putting the together in a container. It means, as Brennan rightly says, “re-imagining and re-conceptualizing” the medium and the ways it can be used as a mediation of meanings.

**Considering the designing process**

Brennan uses the phrase “re-conceptualizing the book” and Wikerson-Jerde points to a design ecology that can be leveraged so that constructionism enters the broader discourse and theoretical landscape in education. Constructionism is about constructivist learning through bricolage with artifacts that take on the role of living expressive media and join up with other semiotic systems for externalizing thought, such as written and spoken language and gestures (Morgan & Kynigos 2014). It is thus not surprising that, like constructivism, constructionism addresses social interaction, paying special attention to the mediation of artifacts as representations of thought. Constructor design in collectives allows for the generation of meanings in a setting where these meanings are densely expressed as the artifacts being built are made public and subject to eternal change. I found it thought-provoking to consider creativity in this kind of context. Seymour Papert points out that it is possible to create environments rich in opportunities for meaning making (Papert 1980). Communities of interest aiming to come up with original resources made possible by new kinds of digital media can be considered as rich environments for creativity and meaning generation. Creative thinking can be thought of as an inherent ecological element in a culture of participation (to use Gerhard Fischer’s 2013 term). In this sense, this kind of environment is indeed dense in meaning making and should be considered, as Wilkerson-Jerde aptly suggests, for all kinds of social orchestrations, including students and diverse professionals. This poses important research questions. How can such socio-technical environments be supported and how can social creativity have richer opportunities to emerge? To do this, how can we leverage diversity in the participants of such a group? Wilkerson-Jerde suggests building on existing practices as one of the ways to generate creativity. The c-book evokes structured and linear information transfer, as Brennan points out, so how can we help so that existing practices and experiences spark creative thinking rather than frame it? How can a new kind of mediation emerge when we look at and build on practices using media in traditional ways?

**Prospectively organizing and understanding collective design**

How can we understand the process of collective design with respect to the ways in which meaning generates in the individual members as they act and interact to participate in a joint enterprise? Wilkerson-Jerde points to the need for humble fine-grained theory emerging from forging connections amongst relevant frameworks (§5). In my target article, documentational genesis, boundary crossing and constructionism were selected as frameworks pertinent to the study at hand, and the process of connecting and elaborating a fine-grained theory was under way. In my view, this places constructionism in an interesting and challenging position. It gains an identity in amongst related frameworks and offers a special insight into new research ventures, such as the one in the case of my target article, to understand meaning generation and social creativity in special designer communities. Frameworks are tools built to illuminate aspects of a meaning-making process drawing from experiences in particular contexts (Artigue & Marioti 2014). After an initial period of elaboration, they often become objects of criticism for not illuminating other aspects, just as radical constructivism was originally criticized for ignoring social interactions and socially generated meanings (Riegler & Steffe 2014) and constructionism for ignoring the role of the teacher. As suggested in my target article, in recent years there have been efforts to draw connections between such frameworks, to draw from the experience and the richness but also create some cohesive sense of the knowledge built through research. Constructionism should have a place in the landscape of frameworks; the process of building humble theories drawing fine-grained connections between constructionism and other frameworks such as those above contributes to our knowledge and also places constructionism in an identifiable role in amongst theory. As Wilkerson-Jerde points out, a “new ecology of constructionist design” (§3) may provide a rich environment for us researchers to generate knowledge in a process where constructionism plays a necessary and structural role.

*Accepted: 3 July 2015
Received: 3 July 2015*
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Building Bridges to Algebra through a Constructionist Learning Environment

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Introduction

There is a growing concern that despite the increased availability of digital technologies designed for mathematics learning, students rarely use ideas, concepts or strategies that they could acquire through their interaction with such technologies in other contexts (cf. EACEA Eurydice Report 2011). As such, the full or intended potential of such technologies is diminished. One of the earliest (and most articulate) examples of these concerns is discussed in Jean-Luc Gurtner (1992). Referring to the Logo environment, Gurtner demonstrated that the tool’s features, which are designed to support students when faced with complex mathematical problems, may impede them from making connections between their work in Logo and any mathematical or geometrical ideas they are already familiar with and use when problems seem less complex. One of the reasons behind this is that students might know how to use a digital tool procedurally, but can fail to understand conceptually the mathematical concepts and procedures that the tool was designed to help them with. Therefore the tool cannot immediately become an efficient mathematical instrument for them (Artigue 2002). Consequently, teachers can be hesitant to use such tools as it is hard for them to be convinced of the tools’ value and they are reluctant to dedicate time to learning how to use them effectively and incorporate them into mathematics teaching practice (Clark-Wilson, Robutti & Sinclair 2014). However, a growing awareness of digital technologies’ potential and limitations can support teachers using these technologies in the classroom (Abboud-Blanchard 2014). In this article, we discuss our approach to supporting students’ transition in moving back and forth from paper-and-pencil to interacting with digital tools. We therefore consider ways of facilitating the integration of digital technologies into the mathematics classroom in an effort to shed some light on this issue that did not have the attention it deserves, as yet. In particular, our focus is on the transition to formal algebra and how students “transfer” their knowledge from their interactions with an algebraic micro-world – a constructionist learning environment (eXpresser) specially designed to support and address students’ difficulties with learning algebra (see Mavrikis et al. 2013) – to paper-and-pencil (PaP) activities.

We are not the only ones concerned with the transition to formal algebra (e.g., Radford 2014), and the literature is replete with examples of student difficulties (e.g., Stacey & Macgregor 2002). Our view is similar to that of Luis Radford (2014), who claimed that there is a need for specially designed classroom activity to support students’ developmental path to formal algebra, and to Gurtner (1992) and Stephen Godwin and Rob Beswetherick (2003), who suggested presenting structured tasks, using appropriate digital tools and making explicit interventions during students’ interactions. We claim that a digital tool specially designed to support the development of algebraic ways of thinking (AWOT), together with carefully designed bridging activities, should scaffold the transition to formal algebra. Besides “learning” the tool and developing expertise in using it, students should be supported in making the connections to the maths.
Considering the issues discussed above, the research carried out in the MiGen project has offered major gains in the understanding of students’ development of AWOT through their interaction with exploratory learning environments. In this article, we present data gathered from 11–14-year-old students who worked on bridging activities carefully designed to support their transition from interacting with the MiGen constructionist learning environment, namely eXpresser, to traditional PaP algebraic generalisation tasks. General conclusions remain based on the initial stages of our data analysis are discussed on this transition to PaP tasks, as well as to algebra in general. Some research outcomes are shared regarding the successful integration of the eXpresser microworld, as well as the successful integration of similar digital tools, into the mathematics classroom.

Theoretical background

Major transitions in a learner’s life are much studied: the transition from counting to number (Cobb 1987), from number to arithmetic (Fuson 1990), from arithmetic to algebra (Davis 1985). The latter transition has been extensively researched and the mathematics education literature has revealed many examples of student difficulties in learning algebra (e.g., Stacey & Macgregor 2002). Students struggle to understand the idea behind using letters to represent any value (Duke & Graham 2007), and are inexperienced with using mathematical vocabulary to express generality (Hart 1981). Even students capable of expressing a general rule through the use of words such as “always” or “every” struggle to use letters and symbols to form algebraic expressions. As James Kaput (1992: 546) put it, students are routinely asked to “learn representation systems without anything to represent.” Instead, the need to express and justify generality can be considered “the heart, root and purpose of algebra” (Mason 2005b: 2).

In the digital era, where digital technologies are increasingly making their appearance in the mathematics classroom, students are faced with another transition, that of moving back and forth from PaP to interacting with digital tools. It is imperative, therefore, to investigate how and whether students “transfer” their knowledge from their interactions with digital tools to PaP activities. We put transfer in quotes because it refers to different constructs for different communities. There is of course a lot of research on “transfer” (e.g., diSessa & Wagner 2005). Our view is aligned with King Beach (2003) who has argued that the metaphor should be viewed as transition instead of transfer, as crossing boundaries from one location to another is in fact a process of transition and he considers that people are the ones who move and not knowledge or learning. Other authors claim that transfer “entails re-use of knowledge, demonstrated and/or acquired in one situation (or class of situations), in a ‘new’ situation (or class of situations)” (diSessa & Wagner 2005). Similarly, Robert Haskell (2001: xiii) claims “Transfer of learning is our use of past learning when learning something new and the application of that learning to both similar and new situations.”

When considering the “transfer” of knowledge, one needs to consider what type of knowledge is being transferred, as the educational literature has revealed many different types of knowledge (Beach 1999; diSessa & Wagner 2005). For example, James Hiebert and Patricia Lefevre (1986) used the existence or lack of connections between internal networks (schemas) to introduce conceptual and procedural knowledge. Conceptual knowledge consists of a connection of networks and is rich in relationships. Procedural knowledge is defined as the learning of a series of actions, where the only apparent connections are those between successive actions in the procedure. The latter type of knowledge is the one that is usually observed with students who interact with digital tools, as they discover how the tool “works” and can rely on the immediate feedback they get from the tool but not necessarily reflect upon their actions nor verify their answers (Hieler, Gurtner & Kieran 1988). Moreover, students tend to ignore interesting perspectives on mathematics while interacting and gaining more and more experience with digital tools (e.g., Gurtner 1992; Godwin & Beswetherick 2003). Saying that though, it is worth revisiting the arguments in Seymour Papert (1980) that students who interact with Logo can visit mathematically rich areas that they would not have approached otherwise. Using digital tools that are specially designed to support students’ difficulties and possible misconceptions on the topic of algebra, for example, should scaffold the transition to formal algebra without rendering it impossible for them to reach the mathematical bank of algebra. Besides “learning” the tool and becoming experts in using it, students should then be able to make the connections to the mathematics behind their digital interactions. The challenge is to find ways to support students to make these connections.

In the case of Logo, Gurtner (1992: 247) considered “the type of connections generally expected, and very seldom observed, between Logo practice and mathematics” as transfer and suggested that “a rather long period of Logo practice (one that is rich in reflection) is necessary before transfer to mathematics can occur (Salomon & Perkins 1987).” He also used the “bridging” metaphor to describe the connections students or educators try to build between different domains or topics within the same domain or aspects of the school life and the everyday life. We valued and aligned our work with the bridge metaphor (as opposed to the notion of transfer) as it allows connections to be identified and made as early as possible between the domain of the digital tool and mathematics and hopefully to have a greater impact on students’ learning.

Relevant research (e.g., Gurtner 1992) and our anecdotal observations suggest that students rarely use ideas, concepts or strategies they seem to have acquired through their interactions with digital technologies in their mathematics classrooms. One way to build bridges to formal maths is through presenting structured tasks, using appropriate digital tools and making explicit interventions during students’ interactions. Even though a lot of research

1 The MiGen project was funded by the ESRC/EPSRC Teaching and Learning Research Programme (Award no: RES-139-25-0381) and the MiGen follow-on project is funded by ESRC (Award no: ES/J02077X/1), http://www.migen.org
has been carried out on how to design such tools to address students’ difficulties with mathematical concepts (e.g., Hoyles & Noss 1996; Noss et al. 2012), the issue of the integration of the tools in question needs to be investigated. This involves looking into what happens after students interact with a digital environment and what resources can render the transition to formal mathematics successful.

9) Despite the advances in the technological infrastructure in schools and the plethora of digital tools specially designed to support the teaching and learning of mathematics, the integration of digital technologies in mathematics education has not always met expectations (e.g., Drijvers et al. 2010). One of the reasons seems to be teachers’ usual practices (Clark-Wilson, Robutti & Sinclair 2014). The teachers’ perspectives and their abilities to develop a new repertoire of appropriate teaching practices for technology-rich classrooms can play a crucial role in identifying the best strategies in supporting the successful integration of digital technologies in the mathematics classrooms (Ruthven 2007).

10) Considering all the above issues, in this paper the focus is on bridging activities specially designed to support students’ transition from their interactions with the MiGen constructionist learning environment to PaP activities outside the tool. We share some research outcomes in an effort to support students, and consequently their teachers, towards a successful integration of the MiGen tool and other similar tools in general into the mathematics classroom.

Methodology

11) Using a Design-Based Research methodology (Design-Based Research Collective 2003), over the past seven years we carried out a number of studies in six different schools in London, worked with 11 mathematics teachers and collected data from 553 students aged 11–14 years old. Our data comprises interviews and transcripts that are one-to-one and with small groups of students, video (mostly screen recordings) and audio files from interviews, observations that are one-to-one, of small groups and of classrooms, detailed logs from students’ interactions in the form of a database and interviews of teachers, and transcripts and bridging activities specially designed to gauge students’ knowledge.

12) We have presented results from our data analysis of our various studies in a number of papers (e.g., Mavrikis et al. 2013; Noss et al. 2012; Geraniou et al. 2011). In this article, however, we focus on the data collected from the bridging activities students worked on during, but mostly after their final interaction with the eXpresser tool. We present here our initial analysis offering examples of students’ typical responses. We plan to do more in depth analysis for each type of bridging activity, as we started to do in the case of the collaborative activity presented later in the article (cf. Geraniou et al. 2011). Since the eXpresser tool has been specially designed to support students dealing with some well-known and researched misconceptions on algebra (Noss et al. 2012), the goal of this preliminary analysis was to identify the impact of those design decisions on students’ understanding and reasoning about algebraic generalisation, and whether students use any of the strategies they were encouraged to employ while interacting with eXpresser on the PaP tasks and are successful in solving figural pattern generalisation tasks. We focused on two AWOT, as described in our previous work (Mavrikis et al. 2013):

- Perceiving structure and exploiting its power, which is about noticing what stays the same and what is repeated in a figural sequence so as to understand how the sequence is “structured,” supporting therefore “the development of structural reasoning” and the habits of “breaking things into parts” by identifying “the building blocks of a structure” (Cuoco, Goldenberg & Mark 1996); and
- Recognising and articulating generalisations, including expressing them symbolically, which is the process of translating the observed structure in an algebraic expression, using formal algebraic notation to write general rules for numerical sequences. Students’ answers were viewed several times and analysed using those two AWOT as an analytical framework for interpreting students’ strategies.

13) In the results section, we share our insights gained from the initial analysis of this data on bridging activities and students’ strategies to solve figural pattern generalisation tasks without the support or immediate feedback of eXpresser.

The eXpresser microworld and bridging activities

14) The MiGen system is a pedagogical and technical environment that is designed to improve 11–14-year-old students’ learning of algebraic generalisation, a specific and fundamental mathematical way of thinking. Its core component consists of a microworld, eXpresser, which is designed to support students in their reasoning and problem-solving of a class of generalisation tasks. Previous work (e.g., Küchemann 2010; Mason 2005b) has demonstrated in particular the potential of designing activities that can help students focus on the structure of the figural pattern by providing generic examples and challenging them to identify the rules that underlie them. In eXpresser, students construct figural patterns by expressing their structure through repeated building blocks of square tiles, and articulating the rules that underpin the calculation of the number of tiles in the patterns. A typical eXpresser activity asks the student to reproduce a dynamic model presented in a window that appears on the side of the activity screen.

15) Figure 1 shows a model where a row of red tiles is surrounded by grey tiles. Students are asked to construct a model that
works for any number of red tiles, and find a rule for the total number of tiles surrounding the red tiles. They can test generality by animating the model: that is, by letting the computer change the number of red tiles at random. The design of eXpresser capitalises on animated feedback and on the simultaneous representation of a specific and general model (“My Model” and “Computer’s Model” in Figure 2), built by combining patterns and on the close alignment of the symbolic expression, the Model Rule and the structure of the model. In the Computer’s Model, a value of the variable2 (“Num of Red Tiles” in this example) is chosen automatically at random (it is “7” in Figure 2) and will generally be different from that in the specific model (“4” in Figure 2). So the Computer’s Model indicates to students whether their constructions are structurally correct for the different values of the variable(s) assigned to the various properties. Students also construct a model rule for the total number of tiles, and validation of its correctness is made evident by colouring: tilings are only coloured if the rule for the number required is correct.

2 | All numbers in eXpresser are constants by default, referred to as “locked” numbers. When the user “unlocks a number,” it is possible to change its value; it becomes a variable.

3 | Some eXpresser tasks can be found on http://expresser.lkl.ac.uk

4 | The consolidation activities are designed to accompany eXpresser activities and therefore all models, e.g., the grey train-track model presented in Figure 4, are animated in eXpresser when shown to students.

5 | For these tasks, students’ models are not necessarily presented for the same Model Number. Instead students are encouraged to explore and trial different values for the Model Number and quite often they were observed using the same value for their Model Number so as to compare the two models and rules (see Geraniou et al. 2011).
Consolidation Task – Train-track

1. How many tiles are needed for Models 4, 8, 1 and 100?
2. If we use “M” to stand for the Model Number, how many tiles are needed for Model M?
3. Use the space below to explain the different parts of your rule — use the diagrams left or your own if it helps.
(Notet: Task models for these tasks are presented animated in eXpresser)

Collaborative Task – Equivalent expressions

1. Convince each other that your model and rules are correct.
2. Can you explain to each other why the rules look different but are equivalent? Discuss and write your explanations.

eXpresser-like Paper Task – Bridges

1. Find the rule for the number of tiles for any Model Number.
2. Find the number of tiles for Model Numbers 5, 10 and 100.

Text-book Paper Task – Tables and Chairs

1. Find the general rule for the number of chairs for any number of tables.
2. Use your rule to find the number of chairs for 20 tables and for 200 tables.
3. If I have 26 chairs, how many tables do I need?

Figure 4 • Examples of the 4 types of Bridging Activities.
Students were asked to work independently on all the types of bridging activities, except for the collaborative one, for which they worked in pairs or groups of three. Using the two AWOTs mentioned earlier as an analytical framework for interpreting students’ strategies when undertaking the bridging activities, we present our initial results under those two headings.

**Perceiving structure and exploiting its power**

For the consolidation tasks, most of the 175 students demonstrated on the model figures presented on paper how they visualised the structure of the given model. In Figures 5, 6, 7 and 8, we present some examples of students’ answers on the “Train-track” consolidation task, the “Equivalent expressions” collaborative task, the “Bridges” eXpresser-like paper task and the “Tables and Chairs” textbook-like task respectively. Students clearly marked the different parts that would remain the same in any instance of the pattern and the parts, which, repeated every time, create the different instances of the pattern. Some of them, perhaps influenced by the colouring feature of eXpresser, used coloured pens to identify these different building blocks. Students demonstrated a variety of ways to visualise the task patterns and they seemed to be as influenced by the eXpresser’s features as they were using the eXpresser terminology, e.g., number of building blocks or models. For example, in Figures 7 H, 7 I and 7 J, students drew the two building blocks that they could use if they were solving this task in eXpresser, that of a column of three square tiles and that of an “L”-shaped one of five tiles. For example, Janet named her independent variable as “number of red BBs” (BBs stands for Building Blocks), and even though Nancy named hers as “Nancy,” she used eXpresser’s terminology in her discussions with Janet (see Figure 6). Especially for the collaborative task, most students verbally identified their building blocks in their models and rules and compared them to conclude about their equivalence. An example of two students’ collaboration and its outcome is presented in Figure 6.
In Figure 7J, the student has derived two “theories” as they describe the two ways in which they were able to construct the Bridges model. In both these cases, they clearly identified the building blocks that are repeated to form the task model and used different colours to indicate which blocks, for example, need to be removed from the constructed model so that the task model is produced (two grey tiles for “Theory 1”) and which building block would be added as an extra one to complete the task model in “Theory 2” (the green building block of three tiles). For their “Theory 2,” they also indicated clearly that the blue tiles are used for the “repeating model,” whereas the green tiles are used for the “not repeated model.”

In all these examples, it is evident how many different ways students have visualised the task models. There were also a few students who managed to derive a correct general rule, but they did not demonstrate on paper the structure in which they possibly visualised the pattern. Such an example is given in Figure 7F.

Recognising and articulating generalisations, including expressing them symbolically

Students seemed to rely on the structure of the given task model in order to articulate a general rule. Most of them provided clear explanations to justify their derived rules and share their solution and revealed some fluency in using the formal algebraic language. They identified what stayed the same and translated that into a constant in their rule. For example, in Figure 7J, the student had even annotated his/her rule $(5 \times M) + 3$. He/she showed that the coefficient 5 is the number of building blocks in his/her second building block, which, as he/she claimed, is repeated. The constant 3 is the number of tiles in their first building block, which is not repeated, and “M” is the “model number.” Similarly, the student in Figure 7i successfully identified two building blocks that can produce the task model, and indicated which building block stays the same and which is repeated.

Students’ answers revealed their ability to articulate general statements, such as “with every new model, another 7 is added and if there’s “M” amount of models, it should be $(7 \times M) + 5$” (Figure 5A) or “there are always 2 chairs to the ends of the single tables, then 2 chairs on the end of all tables put together” (Figure 8K). But the crucial step was their ability to translate that generalisation in parallel to their visualised structures into general rules, as well as to argue about similarities (or differences) between their models and derived general rules when discussing rule equivalence (e.g., Figure 6). Most students used the eXpresser language and terms such as “model number” to represent the variable in their rule (e.g., “$5 \times$ whatever model number $n$ is $+ 3$,” Figure 7F, as an intermediate step before expressing their derived rules in a formal algebraic expression (e.g., “$(5 \times M) + 3$,” Figure 7J)). eXpresser seems to have influenced this outcome, as it encourages students to name their variables (“unlocked” numbers) based on what its various values represent and therefore allows students to give meaning to that variable. This step eased students’ transition to the formal algebraic language and seems to have given meaning to the use of letters to represent “unknown” values.

Some students evaluated their rules by using specific values for their variable and used these examples to justify further their derived rules. For example, in Figure 7J, the student calculated the number of blocks for Model Number 50 and found that there are 253 blocks. As they had derived a second rule, i.e., $5(m + 1)–2$ (top corner of the Figure 7J), they could see that for the same Model Number 50, both rules give the same number of building blocks. In Figures 8K and 8L, even though both students justified in words how they derived their rules, they even used numerical examples, choosing 7 chairs and 50 chairs respectively.

Of course challenges remain, and even though the presentation of each of the bridging activities was carefully designed to prevent students from looking for the term-to-term rule in a sequence, there were some cases of students, especially in the text-book like bridging activities, who reverted to their past experiences and worked out the answers for each consecutive term in a sequence. For example, in Figure 8N, the student calculates the number of chairs when having 1 table, then 2 tables, then 3 tables, etc. He/she focused on the term-to-term rule and managed to spot the correct general rule and wrote “Chairs = $tables \times 2 + 4$.”

http://www.univie.ac.at/constructivism/journal/10/3/321.geraniou
This example reveals that the student either solely relied on a term-to-term approach or they used this empirical approach to start with but then switched to a functional view, writing “every table adds in 2 more chairs.” There are of course cases in which students do not transfer the skills which the eXpresser was designed to help them develop. Perhaps there is a need for more interventions through bridging activities to enrich students’ interactions with constant reflections on their strategies and greater emphasis to be given to supporting students who have well-known and researched difficulties. It would have been interesting to investigate whether this student would have used the same strategy when faced with a more complex figural pattern generalisation task, in which such a “term-to-term rule” strategy would not have been easy (e.g., quadratic sequences, which were occasionally given as additional challenging tasks).

Conclusion

Researcher: “So, what did you learn from interacting with the eXpresser tool?”
Student: “I learned how to put tiles and make nice patterns in different colours”
(Excerpt from an early pilot study with eXpresser)

Students nowadays are asked to interact with a number of ICT tools that have been carefully designed and developed to engage them and support their learning of mathematics. Quite often though, students learn how to interact with the tool, create beautiful productions, such as colourful patterns as suggested by the student in the above quote, and often get to the right answer or “an” answer without necessarily reflecting on and consolidating their knowledge during their interactions. They may know how to use the tool procedurally, but may fail in understanding conceptually the mathematical concepts and procedures that the tool was designed to help them with. Consequently, teachers can be hesitant to use such tools in their lessons as it is hard for them in their busy work lives to be convinced of the tools’ short- and long-term value and can be reluctant to incorporate the use of ICT tools into mathematics instruction.

Figure 7 • Examples of 12-year-old students’ work on the eXpresser-like Bridges bridging activity.

This one never changes, it never moves. Separate building block
This one never changes, it never moves. Separate building block
This one does move because it is a pattern and is call M
This block stays where it is
This is the repeated building block

5 x whatever model number it is + 3
The number of strands in the model number +1
For example model 7 has 8 strands
(7+1)=8

F
G
H
I
J

5 x whatever model number it is + 3
This block stays where it is
This is the repeated building block

This one never changes, it never moves. Separate building block
This one does move because it is a pattern and is call M
In the case of the eXpresser tool, and as has been revealed in the few examples presented in the previous section, most students seemed to have successfully “transferred” their gained knowledge or crossed the “bridge” from the eXpresser algebra to formal algebra. They have demonstrated their conceptual understanding of deriving a general rule and allowed us to claim they can generalise and adopt AWOT when solving paper and pencil figural pattern generalisation tasks. Our experience from the various studies for the MiGen project so far has supported the need for bridging activities, whose objective is to make the connections to algebra explicit. The need and value of such activities have been claimed by Gurtner (1992: 253) too, who claimed that “the do-math-without-noticing-it philosophy of Logo can be abandoned in favour of techniques that explicitly present looking for connections between Logo and mathematics as an objective of a task.” We also recognized the need for constant reflections by students when interacting with the eXpresser tool, which was achieved through the consolidation tasks. Similarly to our research outcomes, Godwin and Beswetherick (2003), when investigating the use of Omnigraph in the classroom, claimed that there is a need for tasks that encourage more focused interactions by students in an effort to help them formalise and concretise their generalisations, notice relevant properties and develop mathematical ways of thinking. There also seems to be a need for a long period of practice with the eXpresser tool, and any mathematics digital tool, rich in reflection and consolidation, before transfer to mathematics can be deemed possible. This view has been supported by other researchers in the past (e.g., Noss et al. 2012; Gurtner 1992; Godwin & Beswetherick 2003).

Finally, we do not claim that our approach to bridging activities is the only way to encourage transfer, neither that eXpresser is the only environment to help students develop AWOT. However, as we have elaborated in Mavrikis et al. (2013), the interaction with eXpresser provides a substrate of activity and experience for the teaching and learning of algebraic generalisations that is difficult to achieve with traditional paper-based activities (perhaps with notable exceptions of concentrated research efforts, e.g., Küchemann 2010). This is the case for other areas of mathematical learning as well, and although digital tools like eXpresser provide part of the answer, the article demonstrated how carefully designed bridging activities may be of value.

In a series of projects related to the eXpresser tool we have engaged with a number of teachers, trainee teachers or mathematics educators, and encouraged them to co-design activities around eXpresser and to use them for teaching. We have seen several creative approaches directly or indirectly aiming towards the objective of making links between students’ experience with eXpresser and algebra. For example, teachers have designed activities that invite students themselves to design eXpresser tasks and challenge their peers or create posters to share their views of eXpresser, its activities and what they believe they have learned during their interactions and to identify similarities to traditional algebra. There are several examples of this in the MiGen follow-on package resource (http://link.lkl.ac.uk/migen-package), and the M C Squared project (http://www.mc2-project.eu).

Figure 8 • Examples of 12-year-old students’ work on the Tables and Chairs textbook-like bridging activity.

K

L

M

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project.org) involves a community of interest that is designing a c-book around these ideas.

« 29 » There are of course several tools, ranging from mathematical games to elaborate production or programming tools, where students are given the opportunity to use or develop skills in order to solve puzzles or create and share artefacts. But the concern for us (and teachers we interact with daily) is the same as mentioned above: what is the residual knowledge that gets noticed by the interaction with such a tool and how can we make it more explicit and support the learning of mathematics in constructionist learning environments?

« 30 » A successful integration in our view involves the transition from interacting with a digital tool to the awareness of the knowledge that can potentially be transferred from students’ interactions with digital technologies to PaP activities, and identifying ways to encourage explicitly the sustainability of such knowledge. Taking into consideration this vision, our aim remains to investigate further the issues of “transfer” and “bridging” and support the implementation of digital tools in the classroom through carefully designed and innovative bridging activities that consolidate, support and sustain students’ mathematical ways of thinking.

Received: 22 February 2015
Accepted: 24 April 2015

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Open Peer Commentaries on Eirini Geraniou & Manolis Mavrikis’s “Building Bridges to Algebra through a Constructionist Learning Environment”

Proposing a Framework for Exploring “Bridging”
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> Upshot • Geraniou and Mavrikis raise the important issue of “transfer,” when students transition from activity in technological tools to paper-and-pencil tasks. In this commentary, I contribute to the conversation by focusing on the relationship between task design and students’ development of knowledge.

1 Education researchers have tried to describe the situated nature of knowledge that students construct as they interact with contextual problems and digital tools. Examples include the notions of “abstraction in context” (Hershkowitz, Schwarz & Dreyfus 2001), “situated generalizations” (Nemirovsky 2002) and “situated abstractions” (Hoyles & Noss 1992). What is common among these notions is the idea of constructing knowledge that is situated in the specific context in which that construction takes place. Although powerful for developing advanced mathematical ideas, “there is, however, little evidence that students can abstract beyond the modeling context” (Doerr & Pratt 2008: 272). Eirini Geraniou and Manolis Mavrikis make a significant contribution to the field by raising the issue of the “transfer” of students’ constructed knowledge from the eXpresser digital environment to paper-and-pencil activities.

2 The authors study “transfer” through a series of what they refer to as “bridging activities” to assist the “transition” to formal algebra. Unlike Harry Broudy’s (1977) notion of “applicative knowing” or the ability of students to apply their prior knowledge in order to solve new problems, Geraniou and Mavrikis’s goal is not just about replicating or applying knowledge but rather about placing students “on a trajectory towards expertise” (Bransford & Schwartz 1999: 68) by scaffolding the transition to formal algebra. In order to make this distinction, they take a view of transfer that is aligned with King Beach’s conception of transfer as “transition,” since “people are the ones who move and not knowledge or learning” (Beach 2003: 3). Although the authors describe the notions of “transfer,” “bridging” and “transition” as separate but inter-related, at points throughout the article these are used interchangeably. In my view, Geraniou and Mavrikis’s goal of transfer aligns with the metaphor of “bridging” as “a process of abstraction and connection making,” as described by David Perkins and Gavriel Salomon (1988: 28). Consequently, bridging can be seen as expanding what Dave Pratt and Richard Noss (2002, 2010) refer to as students’ contextual neighbourhood, or the range of contexts and variety of circumstances in which the students’ knowledge is made relevant and accessible.

3 By using a design-based research methodology, Geraniou and Mavrikis designed a series of “bridging activities” to explore how students use the situated knowledge they constructed through their activity in eXpresser to solve similar paper-and-pencil (PaP) tasks, namely:

- Consolidation tasks
- Collaborative tasks
- eXpresser-like paper tasks
- Textbook paper tasks.

Since context plays such a vital role in this study, in this commentary I raise some design issues that can be considered while studying the notion of bridging. First, I would like to challenge the authors to define what they mean by “context.” If the goal of the design-based research is to develop a contextual variety of bridging activities aimed at broadening the scope of the mathematical abstractions in the eXpresser activities, then the choices of context in the four PaP tasks need to be made explicit.

4 The choice of context is influenced both by the initial eXpresser context and by the two algebraic ways of thinking (AWOT) that the authors aim to explore, namely:

- Perceiving structure and exploiting its power; and
- Recognizing and articulating generalizations, including expressing them symbolically.

Design studies involve “engineering” particular forms of learning and systematically studying those forms of learning within the context defined by the means of supporting them” (Cobb et al. 2003: 9). Likewise, the process of “bridging” can be “systematically” studied by making the iterations of the task design process explicit and presenting how students’ development of AWOT informed the design of those iterations. In other words, it can be studied by exposing the study’s iterative nature, where researchers formulate conjectures about student learning and then revisit and refine them throughout the study (Cobb

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A mechanism showing the process of designing those tasks (e.g., nature, sequence) that makes explicit the choices of context, the iterative cycles of design, if any, and the conjectures the authors had about students’ progression of thinking while working with those tasks could provide a stronger framework for studying the “bridging” process.

“5” Simon’s (2013) design approach to learning through activity may offer a guide to structure this bridging framework through a sequence of four steps:
1 | Assess students’ relevant mathematical conceptions;
2 | Articulate a learning goal;
3 | Specify an activity that students currently have available that can be the basis for developing the abstraction specified by the learning goal; and
4 | Design a task sequence and postulate a related learning process.

Geraniou and Mavrikis constructed a model of students’ thinking in xPresser, clearly described the two AWOT they have as learning goals, developed a sequence of tasks for reaching those goals and began their task design by having students’ activity with xPresser as the basis. What needs further investigation is the hypothetical learning process (Simon 2013, 2014), which takes the form of conjectures about student thinking and how the specific engineering of the task design and sequence may assist students in developing their knowledge and reach the AWOT goals. Questions that may guide this process include:

- What schemes and operations of AWOT were provoked in the initial context of xPresser?
- How can similar schemes and operations be provoked in the new contexts?
- What could be the thinking of the student in those tasks that would explain “bridging”?

“6” Subsequently, the “bridging” process can be described by constructing models of how students’ thinking developed through the research process (Cobb & Steffe 1983; Thompson 1982). These models will portray a trajectory of students’ development of AWOT that consists of an explanation of students’ initial schemes, explanations of changes in those schemes, and analysis of the contribution of the activities involved in those changes (Steffe 2003, 2004). A description of students’ intermediate changes of thinking from the initial to the final AWOT would show the dynamic perspective of “bridging” as a process that evolves through design. The authors provide an example in their discussion of the development of the second AWOT, where they present the “intermediate step” of students’ use of the xPresser language to represent variables in the rule before they express their derived rules in a formal algebraic expression. “Bridging” would then be described as the process of how students’ knowledge has been developed, modified, adapted or even refined during the learning process by identifying those “intermediate steps” as landmarks that build up to algebraic generalization.

“7” In this commentary, I have tried to contribute to the conversation by raising some issues that I consider essential to the “bridging” design and also presenting some suggestions of how students’ thinking during the bridging process can be described and studied. My goal was to initiate a conversation of how a mechanism that explains the relationship between task design and students’ development of knowledge can provide a framework for “bridging.”

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Received: 22 May 2015
Accepted: 16 June 2015

Building Bridges that are Functional and Structural

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> Upshot • In their article, Geraniou and Mavrikis describe an environment to help children explore algebraic relationships through pattern building. They report on transfer of learning from the computer to paper, but also implicit is transfer from concrete to abstract contexts. I make the case that transfer from abstract to concrete contexts should complement such approaches.

“1” In their target article, Eirini Geraniou and Manolis Mavrikis investigated how knowledge developed in a microworld environment, called MiGen, might transfer outside of that environment. They describe a sequence of “bridging” activities to aid students’ transition from the computer to paper-based tasks. Students start with learning about the environment and constructing and describing generalised patterns within it, and then move on to paper-based activities that at first resemble the MiGen environment before taking the form of “textbook or exam-like tasks” (Figure 2). That is, the digital environment provides scaffolding to help students construct knowledge and the bridging activities provide fading to where “attention is purely on the mathematical notation and the mathematics of solving equations” (Hewitt 2014: 26).

“2” The MiGen environment needs to be learned and experienced for a sustained time. The authors report that students received two lessons designed to familiarise them with the environment, and conclude that students need “a long period of practice […] before transfer to mathematics can be deemed possible” (§26). Moreover, Geraniou and Mavrikis state that the literature and their own experiences “suggest that students rarely use ideas, concepts or strategies they seem to have acquired through their interactions with digital technologies in their mathematics classrooms” (§8). Microworlds take a lot of work, and success,
Constructionism

Building Bridges that are Functional and Structural

Ian Jones

in terms of transfer to non-digital contexts, is far from guaranteed. So is it worth the trouble?

« 3 » Constructionists argue that microworlds provide a powerful resource for immersing learners in mathematics. Abstract objects and concepts become tangible, allowing trial and error experimentation, mental reflection and discussion (Papert 1980). Students might then discover and explore ideas that are otherwise be inaccessible to them, and can be challenged in ways not always supported by typical classroom activities. Some readers of this journal will have experienced and studied this enabling power of microworlds. In my own research, students working in the SumPuzzles environment interacted with formal arithmetic equations in distinctly algebraic ways, focussing on structure not calculation, and did so with minimal explicit instruction (Jones & Pratt 2012). However, when the plug is pulled, is the knowledge constructed by the student switched off along with the computer? Work such as that by Geranioti and Mavrikis is important for exploring how students might be bridged to working with formal mathematics on paper, and helping to evaluate whether the scaffolding and fading payoff is worthwhile.

« 4 » Another form of transfer, or perhaps more accurately transition, is implied in the research; namely, the shift from arithmetic to algebraic ways of thinking. The authors report that many students were successful with the final bridging task, and so claim that students “can generalise and adopt [algebraic ways of thinking] when solving paper and pencil figural pattern generalisation tasks” (§26). However, there were exceptions in which students “reverted to their past experiences and worked out the answers for each consecutive term in a sequence” (§24). Researchers working in the early algebra field will be unsurprised by this. Years of learning arithmetic using conventional notation has been shown to develop “operational patterns” (McNeil & Alibali 2005), such as the expectation of a numeric answer and a propensity to perform calculations even when they are irrelevant to the task goal. Moreover, operational patterns are stubborn and can be triggered unhelpfully by traditional paper-based tasks (McNeill 2008). Carefully designed microworlds can free students from operational patterns in order to explore algebraic ways of thinking, but operations are likely to be prioritised again for some students when returning to more traditional presentations of mathematical tasks.

« 5 » At the heart of the MiGen philosophy is another important aspect of transfer, the shift from concrete to abstract knowledge. This has been a contentious issue of late, with a high-profile paper by Jennifer Kaminski, Vladimir Sloutsy and Andrew Heckler (2008) claiming mathematical ideas should be introduced in abstract contexts to ensure better transfer, and others challenging their finding (e.g., De Bock et al. 2011). The use of generalised patterns to support algebraic ways of thinking has been termed “functional approaches” (Kirshner 2001). Appeals are made to children’s experiences of pattern and regularity, and tasks are designed such that formal algebra offers a powerful medium for describing and generalising patterns. Alternatives, which are perhaps less visible in the literature, are “structural approaches.” These start with the abstract (that is, formal symbols and their structural relationships, with no concern for real-world referents) and seek to nurture conceptual understanding that can be transferred to new contexts, be they abstract or concrete. Structural approaches perhaps have a tarnished reputation, sometimes being associated with “meaningless” arithmetic and algebraic drill. However, carefully designed tasks can enable interactions with formal notation and associated transformation rules in a rich, meaningful and educationally valuable way (Dörfler 2006). Microworlds that take this approach have been found to motivate engagement with algebraic ways of thinking about formal notation systems (Hewitt 2014; Jones & Pratt 2012).

« 6 » There are two potential reasons to consider structural approaches as complements to functional approaches. First, whereas functional approaches typically end with the production of a formal expression or equation used to describe a concrete referent (typically a pattern), structural approaches enable the exploration of how formal expressions can be transformed; the notation becomes a medium for doing mathematics rather than describing mathematics. Second, structural microworlds start with formal notation, a virtual and manipulable symbol system that closely resembles that typically seen in textbooks and classrooms. Therefore, transfer from a digital to a paper-based domain might be relatively natural and intuitive for many students.

« 7 » We can assume that constructionist approaches to introducing formal algebra naturally align with both functional and structural approaches. Indeed, both approaches have been shown to lend themselves to the design of microworlds that enable tangible exploration and testing of conjectures such that formal symbol systems become a natural and useful medium of mathematical learning. Ideally, we might want learners to shift flexibly between thinking about concrete referents such as generalisable patterns, and thinking with formal symbols and their transformation rules. Such a fluid and dialectic mixed-approach might be expected to strengthen algebraic experience and understanding, and so promote transfer in the broadest sense of the term.

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Received: 4 June 2015
Accepted: 16 June 2015

http://www.univie.ac.at/constructivism/journal/10/3/321.geraniou
Bringing Reflection to the Fore Using Narrative Construction

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> Upshot • In striving to support transition or bridging between arithmetic and algebra through software, Geraniou & Mavrikis came up against the need for learners not simply to “reflect” on what they have been doing, but to withdraw from action every so often, consider what actions have been effective, and construct their own narrative to hold together actions and goals and connections to past experience with other topics.

“1” The reason we give learners mathematical tasks to do is, I conjecture, that we want them, through their subsequent activity, to encounter mathematical themes, make use of mathematical concepts, employ mathematical procedures, and experience the use and development of their mathematical powers. We want them to “learn” something, which must mean to integrate into their functioning new actions, or variations on already integrated actions. Such actions may be visceral or virtual, taking place in the material world (including e-screens), in the imagination, and with symbols.

“2” Unfortunately mere experience is not sufficient for learning, for integrating into one’s functioning, or for making more and more effective actions available to be enacted in the future.

“4” Enter the MiGen project, which offers not a means of doing calculations, nor of achieving some virtual task, but rather an expressive medium with manipulative, iconic, and symbolic elements. MiGen is an attempt to provide learners with a supportive but undirective environment in which to encounter and express generality, and to bridge the gap between informal expressions (in words and actions) and formal use of symbols. Its intention is to encourage and enable generalisation, to capture invariant relationships between a term of a sequence and the number of that term.

“5” What Eirini Geraniou and Manolis Mavrikis are looking for in their chapter is evidence of transfer, or in the language of situated cognition, evidence of the broadening of the scope of situatedness within which mathematically useful actions come to be enacted. In their study, they discovered the necessity of prompting learner reflection in mid-action (consolidation tasks), not simply at the end as implied in most interpretations of Polya’s fourfold framework. This is an important part of reflection.

“6” It is absolutely vital for learners to withdraw from the action and reflect. Although reflection has been worked on and elaborated by many authors (too many to begin listing), it is rarely evident in classroom practice. My conjecture is that this is largely why the use of digital technology has not resulted in widespread improvement in mathematical thinking: the medium is the message (McLuhan 1964) in that it is so fully engaging, so accomplishment-driven that it is difficult to remember to learn from the experience. Turning off or away from a motion-colour-sound-rich medium is even harder than putting down an absorbing book; there is a sudden hiatus or vacuum before attention re-enters the world outside the medium, and in that hiatus intentions, desires, insights, and experiences can evaporate all too readily. The notion of situated abstraction (Noss & Hoyles 1996) is one attempt to articulate the gap between actions enacted in one context but not in others. Returning to James again,

“7” In modern parlance, this comes out as “we are our attention; we are where our attention is.” Virtual e-screen worlds are inhabited very differently from the material world, or even the world of mental imagination. People in the same situation think, feel, and act differently; indeed, the same person may feel, act, and think differently at different times in what seems to be the same or similar situation, much to the consternation of teachers. Continued and engaged presence in a particular micro-world is likely to engender people into the vocabulary, the discourse of that micro-world, which is why it is incumbent on teachers to enrich learners’ experience with technical vocabulary that provides access to experiences below a surface level of description. As Geraniou and Markolis report, this certainly happened with MiGen, with many subjects continuing to use the same vocabulary in paper and pencil tasks. Yet some reverted to more established ways of thinking (term-to-term rather than direct expression of relationship between term member and term value) in subsequent tasks. Of course the well-honed mathematical thinker whose awareness has been educated is flexible, using whatever actions seem most appropriate, while the pro-
procedure-mastering learner whose behaviour has only been trained is more hidebound, more routine in the actions they enact.

« 8 » Fostering and sustaining a constructive stance to learning involves more than providing engaging tasks, more than encounters with pervasive mathematical themes, more than experience of one’s own use of natural powers in a mathematical context. It requires immersion in and prompts use of a vocabulary that captures those experiences and enables learners to become aware of what has been effective and what has not, not only at the end of a piece of work, but throughout. It is the construction of a personal narrative, with on-going improvements and refinements, that constitutes learning in the fullest sense of the word.

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Received: 29 April 2015
Accepted: 15 June 2015

Authors’ Response:
Let’s Cross that Bridge…but Don’t Forget to Look Back at Our Old Neighborhood
Eirini Geraniou & Manolis Mavrikis

> Upshot: This response addresses the main points from the three commentaries, focusing particularly on additional terms and concepts introduced to the bridging metaphor. We further clarify our call for future research in the area and conclude with reflections about the practical implications emerging from our target article and the commentaries.

« 1 » In her commentary, Nicole Panorkou explicitly reminds us, among other relevant literature, of the concept of contextual neighbourhood from Pratt & Noss (2010), which of course permeates our research due to the direct and indirect influence of the research of the authors in our work. In §3, Panorkou challenges us to define our context explicitly. Revisiting Pratt & Noss (2010), we are reminded that in design-based research, the determination of contextual neighbourhoods is sometimes implicit, both in the case of software design, as in eXpresser, and in the case of task design, as in our paper-and-pencil activities. The challenge with making context explicit is that it is in the eye of the beholder. We therefore have at least three contexts to elaborate on — researcher, student, and teacher or schooling contexts. In brief, the framework of algebraic ways of thinking (inspired by Seymour Papert’s 1972 reference to mathematical ways of thinking) gave us, as researchers, the lens through which to examine students’ activities and learning as well as a way to map those to the teacher and the schooling parlour (e.g., in our case, to the national curriculum). These contexts of course overlap, and perhaps the distinction is mainly academic, but we are primarily interested in the context as perceived by the students and its influence in the knowledge or ways of thinking that they develop.

« 2 » We see therefore the rest of Panorkou’s review as a call for future research, particularly her excellent suggestions, in §§5f, on how students’ learning trajectories between contexts, facilitated by bridges, can be studied. We see our article as a first step towards this investigation. The “bridging” activities were a design-based research outcome after carrying out a number of studies; they therefore served a purpose in the research context rather than the object of investigation itself. We agree, however, that future research should be structured in ways that bring out the dynamic nature of the bridging activities and (sticking with the metaphor) help investigate what situated abstractions (Hoyles & Noss 1992) or other learning takes place on the two sides of the bridge.

« 3 » Along the same line of thought, Ian Jones’s review first brings to our attention a recent paper by Dave Hewitt (2014) that can also help in future research by thinking in terms of scaffolding and fading. In §2, he raises an important question that has troubled us and the team behind the original MiGen project that designed the eXpresser microworld and its tasks: Is the time investment in scaffolding students through one microworld, designed with specific algebraic ways of thinking in mind, worth the trouble?

« 4 » We think that an answer to this conundrum comes on the back of more than 40 years of research in constructionism and endless debates since. Avoiding opening a can of worms in such a short response, our other papers on eXpresser have demonstrated its potential (e.g., Mavrikis et al. 2013), and Jones’s eloquent summary of functional and structural approaches in §§5f provides claims towards the potential of a microworld to support flexibility. Additionally, we rely on anecdotal teacher reports and our experience of the potential of using eXpresser and other microworlds in so called “blended-learning” scenarios, recently popularised by advocates of “flipped learning.” We have seen first hand the potential of giving students eXpresser homework or group projects that can act as substrate for a teacher-led plenary, or subsequent engagement with traditional algebra in the classroom.

« 5 » An additional answer to the point above lies between the lines of the third commentary by John Mason, whose research on mathematics education and his contributions, in particular on algebra learning (Mason 2005a; Mason et al. 1985), have heavily
influenced the design of eXpresser and its associated tasks. Mason refers to the engaging potential of digital technology that can paradoxically lead to a situation that is not conducive to learning per se. Mason invokes George Polya’s “looking back,” which so elegantly frames the aim of our bridging activities. We want to help students to take a step back from the microworld in which they have immersed themselves and remember to learn.

« 6 » Putting all the commentaries together brings us to the title of this article. Engineering (in the sense of Cobb et al. 2003) eXpresser activities interspersed with bridging activities at appropriate time points can answer Jones’s question with respect to efficiency, achieve Mason’s call to encourage students to capture those experiences and become aware of their work by looking back to their interactions throughout the eXpresser tasks, and achieve what Panorkou saw as expansion of contextual neighbourhoods.

Combined References


Elementary Students’ Construction of Geometric Transformation Reasoning in a Dynamic Animation Environment

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> Context • Technology has not only changed the way we teach mathematical concepts but also the nature of knowledge, and thus what is possible to learn. While geometric transformations are recognized to be foundational to the formation of students’ geometric conceptions, little research has focused on how these notions can be introduced in elementary schooling. > Problem • This project addressed the need for development of students’ reasoning about and with geometric transformations in elementary school. We investigated the nature of students’ understandings of translations, rotations, scaling, and stretching in two dimensions in the context of use of the software application Graphs ’n Glyphs. More specifically, we explored the question “What is the nature of elementary students’ reasoning of geometric transformations when instruction exploits the technological tool Graphs ’n Glyphs?” > Method • Using a design research perspective, we present the conduct of a teaching experiment with one pair of fourth-graders, studying translation and rotation. The project investigated how and to what extent activity using Graphs ’n Glyphs can elicit students’ reasoning about geometric transformations, and explored the constraints and affordances of Graphs ’n Glyphs for thinking-in-change about geometric transformations. > Results • The students proved adept using the software with carefully designed tasks to explore the behavior of two-dimensional shapes, distinguish among transformations, and develop predictions. In relation to varied conditions of transformations, they formed generalizations about the way a shape behaves, including the use of referent points in predicting outcomes of translations, and recognizing the role of the center of rotation. > Implications • The generalizations that the students developed are foundational for developing an understanding of the properties of transformations in the later years of schooling. Dynamic technological approaches to geometry may prove as valuable to elementary students’ understanding of geometry as it is for older students. > Constructivist content • This study contributes to ongoing constructivism/constructionist conversations by concentrating on the transformation of ideas when engaging learners in activity through particular contexts and tools. > Key Words • Geometry, transformations, constructionist technologies.

Geometric transformation reasoning in elementary schooling

Geometric transformations (GT) such as translation, rotation, scaling, and reflection can be foundational to the formation of students’ geometric conceptions. The dynamic nature of GT provides students with opportunities to connect a greater breadth of geometric concepts and to engage in higher-level reasoning activities using a variety of representations (Hollebrands 2003). There is significant support for the incorporation of GT in elementary school, even though in the U.S. these concepts are not introduced until the end of middle school. Existing research on early GT reasoning provides evidence that teaching GT to elementary school students is feasible and may have positive effects on students’ learning of mathematics (Kidder 1976; Moyer 1978; Schultz & Austin 1983; Xistouri & Pitta-Pantazi 2011). Many studies in elementary students’ GT reasoning sought to identify the effects of different cognitive styles on the learning of GT (Kirby & Boulter 1999; Willford 1972; Xistouri & Pitta-Pantazi 2011, 2012), the nature of the strategy employed (Boulter & Kirby 1994), and the grade-based ability to perform transformations (Kidder 1976). While these studies provide a picture of students’ understanding of GT, they all do so by using quantitative methods that focus on the improvement of student performance on tests as the result of an intervention, and fail to depict student thinking or to provide evidence for how that reasoning develops. > 2 • We argue that in order to develop children’s reasoning about GT, they must have opportunities to grapple with tasks in which GT are salient. In mathematics, a GT can be defined as a mapping f of A onto B such that each element of B is the image of exactly one element of A. In searching for a more intuitive definition that could guide the process of exploring GT in elementary schooling, we considered the idea of transformation as a change in the position, size, or shape of a figure, and to prompt students to model transformations and generalize about them from working in situated tasks. Students experience such changes in figures in their everyday life when they move and...
Elementary students’ construction

Constructionism

Nicole Panorkou & Alan Maloney

Elementary students’ construction

Youth children already possess a dynamic spatial sense of shape, seeing shapes as malleable – and often provide “morphing explanations” (Lehrer, Jenkins & Osana 1998: 142) for shapes they identify as similar (similar in the sense of resemblance) – and using non-rigid transformations (pulling and pushing sides and vertices) to transform a shape to another shape. Children are able to identify congruency and similarity as early as pre-school (Olive et al. 2010) and have a motion perception of GT by understanding rotations as turns, reflections as flips, and translations as slides (Hollebrands 2004). Consequently, we argue that the teaching and learning of GT can begin as modeling a dynamic motion (Edwards 2003; Hollebrands 2003; Yaglom 1962) to explore “the mental or physical manipulation of geometric figures to new positions or orientations” (Boulter & Kirby 1994: 298) and then expanding these experiences to recognize that GT act on all the points of a figure (eventually, for instance, understanding that translation can be applied to all points in the plane based on a specific direction and distance generally defined by the translation vector (Yanik 2014)).

Consequently, our goal was to create a new activity setting in which students could extend the GT experiences that had been reported in the previous studies. Using new tools, we intended to perturb students’ understanding of GT, and thus promote more sophisticated knowledge about the subject (Noss & Hoyles 1996). We considered the affordances of technology to make this possible through the design of technological tools that expand children’s contextual neighborhood, which, according to Dave Pratt and Richard Noss (2010), “captures the domain over which the idea has been encountered and found to be powerful by the child in explaining the on-screen behaviour” (Pratt & Noss 2010: 94). Our approach was influenced by the notion of “windows on thinking-in-change” (Noss and Hoyles 1996), in which the researcher examines thought processes by introducing new ideas and trying to understand how the thinker connects these notions with their previous knowledge. We considered the design of the “window” to be a fundamental element of the research process, and examined it through Pratt and Noss’s notion of “designing for mathematical abstraction,” which refers to the creation of a domain through which students’ “contextual neighborhoods can be refined and expanded” (Pratt & Noss 2010: 97).

Designing a “window” on students’ GT reasoning

Existing middle- and high-school level studies on GT show evidence of the power of digital technology to create richer opportunities for the study and learning of this concept. Laurie Edwards (1991, 1997) examined the types of generalizations on GT that students made using Logo, finding that the feedback students received on their actions allowed them to generate conjectures about the effect of a transformation on an object, which were then confirmed or disconfirmed by the software. Additionally, the development of dynamic geometry software offered the potential to “build” geometric objects in the software that reflected a structure by connecting ideas and identifying relationships between them, leading to the notion of “figure” as a bridge between unrestrained drawing and the mental geometric idea (Laborde 1995). Geometer’s Sketchpad and Cabri-Geometry have been widely employed as ways to explore high-school students’ views of the nature of GT on a plane, illustrating the power of the “figure” in the development of students’ GT understanding (e.g., Hollebrands 2003, 2007; Laborde 2001). These studies were pioneers in demonstrating how the concept of transformations can be learned in a more dynamic and conceptual way, but they do not provide any information on how this concept can be explored in the earlier grades.

The work of Jere Confrey et al. (2010) offered an entry point to connect the notion of transformations to elementary students’ prior experiences. Graphs ‘n Glyphs (GnG) is a multi-representational,
Educational Research Experiments in Constructionism

Dynamic microworld, developed as part of a longer-term project to study early development of geometric and trigonometric reasoning, that promotes student familiarity with GT as the basis for modeling motion via digital animation in two-dimensional space (Confrey et al. 2006; Confrey et al. 2010). Among the affordances of the environment include students becoming familiar with GT by reflecting, translating, rotating, and scaling shapes on the coordinate plane to complete puzzles. Students are able to direct GnG to perform specific single geometric transformations or sequences of transformations through the use of a timeline, part of the software’s animation sequencer (top portion of Figure 1). For example, having selected (or constructed) a two-dimensional object on a coordinate grid, a student calls up the transformation dialog box, and selects “translation” as the desired transformation (Figure 1). The student then enters the desired values for the magnitude (which students discover includes information about direction) of that transformation (Figure 1). Enactment of the entered transformation in the animation sequencer activates the motion of the object, thus providing immediate visual feedback. Students can reflect on the relationship between predictions about the motion due to a GT, the outcome of the motion animation, and subsequently can construct generalizations of the effects of GT in the plane. By double-clicking on the translation on the animation sequencer, the transformation dialog box re-appears, allowing the students to revise the parameter values for the transformation and re-test their conjectures.

Following a proposition by Judah Schwartz and Michal Yerushalmi (1993: 7) that “important mathematical ideas can be introduced early on in the mathematical education of all students if the introduction is done in the context of interesting and powerful exploratory environments,” we aimed to test the conjecture that offering students an environment in which they use GT to build animations would trigger students’ interest and engage them in a constructive activity to expand the contextual neighborhoods of their GT reasoning.

Studying students’ transformation-based reasoning

We designed an exploratory study to investigate the question “What is the nature of elementary students’ reasoning of geometric transformations when an instruction exploits the technological tool Graphs’n Glyphs?” In particular, we aimed to a) investigate how and to what extent activity using GnG can elicit students’ reasoning about GT and b) explore the constraints and affordances of GnG for thinking-in-change (Noss & Hoyles 1996) about GT. A series of teaching experiments (Cobb et al. 2003) was conducted, based on specially designed tasks using GnG. The initial interview plan and tasks were informed by the ideas embedded in the study of Confrey, Maloney, and colleagues (Confrey et al. 2006). The current article discusses the activity of one pair of students, Nate and Blake, from the fourth grade, who attended an elementary school in the eastern United States. The teaching sessions lasted 40 minutes each and occurred over twelve days.

Considering the limited time that the students were available for the teaching experiment, we had to constrain the specific transformations and dilations that would be required to move one point to another. In order to ensure that students had sufficient prior knowledge of the coordinate plane and angular measurement to perform the designated GT in GnG, students were presented a series of tasks calling for them to identify given points in the first quadrant of the coordinate plane and to determine movements that would be required to move one point to another. Instruction was confined to the first quadrant to avoid confusion with negative coordinate values. Then four different types of tasks were used to introduce translation and rotation. The first two tasks involved physical manipulation and paper-and-pencil grids. Similar tasks were used for scaling and stretching GT.

Table task

Students examined a paper shape (square, rectangle, or triangle) on the table, one at a time, and were asked to close their eyes for 10 seconds. Then they were asked
a series of questions such as “What could I have done to the square/rectangle/triangle?” or “What changes and what stays the same when you do that action?” The purpose was to examine their initial knowledge of GT and to initiate a discussion focused on transformational invariants.

Coordinate plane task

Students were asked to predict one or more GTs (including a sequence, if they found it necessary) needed to modify the location, orientation, and/or size of figure A in order to superimpose figure A onto figure B (referred to as making Shape A “match” Shape B). These tasks required students to translate or rotate shapes in discrete ways. After the students had predicted the necessary transformations, they were asked to use GnG to enact the transformation(s) in the software environment, and to verify their prediction or modify their conjecture, using the visual feedback offered by the software. Figures 2 and 3 show an example of a matching exercise for translation and rotation.

GnG introductory task

Students were asked to perform a specific GT in GnG using the transformation dialog box (see Figure 1). Students initially explored the way GTs are entered into the GnG transformation dialog box, using a task calling for predetermined movements of a single shape either in terms of translations or rotations.

GnG matching tasks

Students were presented two copies of the same figure, A and B. They were asked to translate or rotate shapes in discrete ways. After the students had predicted the necessary transformations, they were asked to use GnG to enact the transformation(s) in the software environment, and to verify their prediction or modify their conjecture, using the visual feedback offered by the software. Figures 2 and 3 show an example of a matching exercise for translation and rotation.

Figure 1

GnG matching tasks

Students were presented two copies of the same figure, A and B. They were asked to translate or rotate shapes in discrete ways. After the students had predicted the necessary transformations, they were asked to use GnG to enact the transformation(s) in the software environment, and to verify their prediction or modify their conjecture, using the visual feedback offered by the software. Figures 2 and 3 show an example of a matching exercise for translation and rotation.

Figure 2 • Example of a matching task requiring translation to move Shape A to match Shape B.

Figure 3 • Example of a matching task requiring rotation to move Shape A to match Shape B.

1. See the website “Learning trajectories hexagon map and descriptors for the Common Core State Standards for Mathematics” by Jere Confrey, Ko Sze Lee, Nicole Panorkou, Drew Corley, and Alan Maloney, http://www.turnonccmath.net, for an important and frequently consulted reference for teachers and professional development providers.
Excerpt 1
Researcher (R): How can you use that to make the square move 8 spaces to the left?
Nate (N): I write 8 on the x [They performed that and it goes to the right.]
R: What did we do wrong?
N: Try minus this time.
R: What is minus?
N: Minus means go down. Try minus this time. Do you have a minus button? [He put –8].
R: Why do you think minus?
N: Because minus means back or take away.

Excerpt 2

Predicted transformations:

<Diagram>

N: We have to do horizontal and vertical, both. Why are there two boxes?
R: You need only one? Try only one.
N: 9 right and 4 up.
Blake (B): We need to go 4 up and 9 to the right.
B: Wait it’s 8
N: No it’s 10
B: The first one is 4 up and 8 right. [They use one box for both values].
R: You are using both values at the same time?
N: Yes it’s the easy way.

<Excerpt 1>
<Excerpt 2>

In this article, we present some episodes from the teaching experiment to provide examples of the generalizations articulated by the pair of students. We initially present students’ thinking of each GT during the paper-and-pencil tasks followed by a description of how this thinking was developed as they interacted with the software tasks. We analyze the generalizations students made while working with GnG in terms of “situated abstractions” – generalizations that students form in order to act in specific mathematical contexts, and which are embedded in the particular context of the actions ( Hoyles & Noss 1992). For example, rotational designations in GnG were designed to be consistent with traditional angle designations on the unit circle, e.g., a positive angle corresponds to an anti-clockwise rotation, and a clockwise rotation requires designation of a “negative” angle; therefore we explored how students’ articulations of GT reasoning were meaningful in relation to the specific features of the GnG environment.

Translations

During the Table task students argued that a shape can slide “up or down, diagonal, or left and right.” After moving to the Coordinate plane task, they recognized that translation involves changing the coordinates of points on the figure, but not the shape and size of the figure. They also identified the location of the vertices in the initial and final positions of a translation, as well as the nature of the change in location. For instance, they determined that “the points are changing to a (7, 5) and a (11, 5),” and concluded that “the vertical line [coordinate] never changes. Only the horizontal line [coordinate] changes.” Students initial articulations show they considered that the figure resulting from a translation was the original figure itself after being moved, having changed its position on the grid (coordinates).

“Minus means go down”

When they began working with GnG, students recognized that when the horizontal change of a translation is positive, the shape moved to the right. Subsequently, we prompted the students to predict how to move a shape eight spaces to the left (Excerpt 1).

Prior to using GnG, students identified the minus sign as the operation of subtraction, stating that “minus means back or take away” or “is like subtract.” But by interacting with the software, they were able to perform vertical translations by specifying movement of shapes upward (+) and downward (–), and experiencing the “minus sign” as the direction that is the reverse of the positive (right or upward) direction. These
situated articulations suggest that students began defining, and distinguishing between, the magnitude and direction of the translation vector. They also began to identify the role of the negative sign contextually as specifying directionality of transformations, instead of only considering it in the context of addition and subtraction calculations.

“The easy way”

Subsequently, the students were challenged to match shapes that required diagonal translations. Although for diagonal translations the worksheets given to students provided two complete panels to permit separate panels for specifying the vertical and horizontal translations (i.e., two transformations), as shown in Excerpt 2, the students entered the horizontal and vertical values in only one of the panels (stating this is “the easy way”), regarding the second panel as superfluous.

The above shows that students were able to define the magnitude and direction of translation vectors in diagonal translations. Coordinating the change of two parameters \((x, y)\) as happening concurrently may be considered to illustrate a situated version of defining a translation vector as a linear combination of the individual component vectors (parallel to the \(x\) axis and parallel to the \(y\) axis) that makes the set of vectors linearly dependent.

“The points have to match”

In attempting to match the shapes, without prompting, students used referents (corresponding points on each shape) to determine the nature of the translation needed in the mapping from the first task on GnG (Excerpt 3).

Although they used correct referents for the first task, they did not do so for the second. However, by trying different values (Figure 4), they concluded that initially they were not using the “correct points,” arguing, “You can take the points and match it up with the other points and see how much it travelled.”

We refer to translation vectors for convenience in this article, and in terms of interpreting students’ situated understanding; however, vector terminology and symbols were not introduced to the students.
In subsequent tasks, we prompted the students to explain their idea of “matching points” in diagonal translations, as shown in the example of the two stars in Excerpt 4. They stated that if they try to match the top vertex of star A to the right vertex of star B, their animation would be wrong.

By experimenting with different values and using the feedback from the resulting translation animations, students noticed that even if they chose different corresponding points, the translation would remain unchanged. They argued that “The only thing you will have to look in order to make it right is that the points have to match,” recognizing that they only had to determine the distance between any pair of corresponding points, a situated recognition that any segment connecting corresponding preimage and image points is congruent to each other and to the translation vector. At this point, we introduced the term “reference points” in order to create a common language of how we talk about the corresponding “matching points” (Excerpt 5).

Students were able to attend to the direction and magnitude of these translations, which would have gone unexamined had they only used motions and surfaces that did not require attention to specific background (grid) position information. These articulations show situated versions of constructing and performing mappings to translate figures and recognized that translation as an operation that acts on figures as a whole by simultaneously acting in the same exact manner on every point within the figure.

### Rotations

Before discussing rotation, the students needed to have understanding of degree as a measure of angle in order to engage with the tasks. We therefore supported the development of this understanding by first exploring angles as wedges of a circle and then as formed by two rays and an endpoint. Students’ understanding of angle was extended to include angles-as-turns by interacting with GnG. After the examination of angles, the sequence of tasks followed the same structure as with the translation tasks.

During the Table task, students identified several key features of rotation, such as “[they can be] clockwise and anti-clockwise” and “[the shape] changes where [the direction] it faces. Its shape would be the same.” When the position of the center of rotation of a shape was changed from the center to one of the vertices of the shape, they gave the example of the Earth to explain the difference (Excerpt 6).

“Minus is clockwise” As the result of a translation in GnG, each point in the figure has changed in the same (additive) way in relation to its corresponding point in the shape's prior position. In a rotated figure in GnG, correspond-
ing points change in relation to rotation around some other referent point (the pivot point in GnG). The single reference point (the center of rotation) is the same for all the points in the figure, and must be specified (unless the default center point of the shape is used). While working with the GnG rotational matching tasks, in order to achieve the desired rotation, the students needed to ensure that the center of rotation was correctly positioned, and to determine the angle for the desired rotation. The students first explored rotation in GnG through a series of prompts to perform rotations around centers of rotation located at various points on the figure. In the software environment, (counter-clockwise rotations have positive angle values, clockwise rotations negative), each group of students extended their generalizations about the role of the negative sign as reversing the (normal) direction of rotation. They explained that they used the minus sign “Because anti means ‘not’ and I thought anti-clockwise is ‘not’ so I tried it;” however, after trying their conjectures they realized that “minus is clockwise.” They used referent positions of figures to estimate the angle of rotation from one position to the next, arguing that a clockwise rotation would be –90 (Figure 5).

“Nate argued that a counter-clockwise rotation could match the shape in Figure 5: “if we do the other way it would be 270.” When he was asked to explain his reasoning he argued that “Because you see that up to here it would be 90 and up to here 180 and up to here 270” showing how he divided the rotation into 90-degree intervals. He reasoned iteratively from the original positioning; it was not clear whether he understands a full circle to be 360 degrees.

“Where you put it [the center of rotation], it makes it stick right there, so when you move it [the shape], it [the shape] rotates around the pivot.” When students were prompted to notice what changes and what stays the same in a rotation, they concluded that all the coordinate points of the shape change while the point of the pivot (center of rotation) remains invariant (Excerpt 7).

Excerpt 7

R: Are all of the points going to change?
B: No.
R: Which points are not changing?
B: The nose point [the center of rotation was initially placed on the “nose” of the fish].
N: No. I think all the points will change.
B: No. See… the pin is there [at the nose point]. The pin is stopping that part. The middle allows it to go everywhere.
R: OK, so the mouth, where the pin is, that point does not change. Now let’s change the pivot [as in the figure below]. What do you think it will happen?

B: Every point that you change it to it’s going to stay. Because the pin is stopping it. Every point you put the pin on, it’s going to stop that point.
R: What is the role of the pivot in the rotation?
B: It moves all the parts except that point.
R: Why it is there?
B: It has to make it in the same place to rotate.
N: Where you put it, it makes it stick right there, so when you move it like… it rotates around the pivot.
R: So you are saying that the fish rotates around the pivot.
N: Yes. And if we take the pivot right there [outside of the fish] the whole fish will move.

“Nate argued that a counter-clockwise rotation could match the shape in Figure 5: “if we do the other way it would be 270.” When he was asked to explain his reasoning he argued that “Because you see that up to here it would be 90 and up to here 180 and up to here 270” showing how he divided the rotation into 90-degree intervals. He reasoned iteratively from the original positioning; it was not clear whether he understands a full circle to be 360 degrees.

“Where you put it [the center of rotation], it makes it stick right there, so when you move it [the shape], it [the shape] rotates around the pivot.” When students were prompted to notice what changes and what stays the same in a rotation, they concluded that all the coordinate points of the shape change while the point of the pivot (center of rotation) remains invariant (Excerpt 7).
Students concluded that in a rotation, the path travelled by a shape around the center of rotation "goes exactly as a circle... It is like an invisible circle surrounding this." Subsequently, we introduced the term "center of rotation" to prompt the students to notice the distance between the shape and its assigned pivot (Excerpt 8).

Excerpt 8
R: The mathematicians named the pivot the center of rotation. Why do you think they gave that name?
N: Because everywhere you put the pivot something has to rotate around it.
R: And is it the center of the rotation?
N: Yes.
R: Why is it the "center"?
N: Because everything rotates around it. I would rather choose "Master of Rotation" because everything rotates around it, whether it is 60 000 miles away it will still rotate around it.

Excerpt 9: A rotation task for which the center of rotation can be located midway between the shapes.

6. Rotate the blue star (Star A) to match the yellow star (Star B).

N: Yes so the center of rotation should go in the middle of the circle so right here [showing the correct spot where the pivot should be placed]. So, you see there is an invisible circle around it Blake? Around both of them...That's why I want to move the pivot right there. In the middle. In the exact middle.
B: Are you crazy?
N: Remember last week we tested it out and we saw that wherever the center of rotation is, something always have to go around it, always something goes around it. It's like the sun and all the planets.
B: I'm not really agreeing with him but I just want to see it.
[They try Nate's conjecture and it works]
R: What if we do clockwise?
N: Then it's same thing but minus.

* 34 * Students concluded that in a rotation, the path travelled by a shape around the center of rotation "goes exactly as a circle... It is like an invisible circle surrounding this." Subsequently, we introduced the term "center of rotation" to prompt the students to notice the distance between the shape and its assigned pivot (Excerpt 8).

* 35 * Up to this point, students could reason about the motion of turning and the role of the pivot but did not consider the relationships between the preimage and image points, on one hand, and the center of rotation, on the other. Therefore, we gave them more advanced matching tasks, which required moving the center of rotation outside of the shape. By experimenting with GnG, they recognized that the center of rotation was a position that can be assigned according to the needs of a particular task, and that it was possible to place the pivot "outside" the shape being transformed. For example, in the task presented in Excerpt 9, Nate recognized that one strategy for rotating shape A directly onto shape B was to place the center of rotation for shape A in the "center" of the space between the two stars.

* 36 * The above examples illustrate that as students solved the rotation tasks, they constructed situated abstractions about the invariance of the center of rotation (for a given rotation), as well as about the distance between the shape and its assigned pivot, recognizing that corresponding preimage and image points are equidistant from the center of rotation.

Retrospective analysis

* 37 * This study showed that students' contextual neighborhoods for GT reasoning could be extended. Instead of relying on only appearance during paper-and-pencil tasks (e.g., the shape stays congruent in translation and rotation, and becomes similar in scaling), it focused on specific properties of particular GT as they worked in situated ways through activities incorporating GnG alongside carefully designed tasks and probing questions. For translations, students talked in situated language about the direction and magnitude of the translation, adopting the notion of the negative sign as an indicator of opposite change. They also discussed translation as mapping in the context of "matching points" or referents, recognizing that the transformation acts on all the points of the figure. For rotations, they extended their generalization about the negative sign as the opposite direction for a rotation, relative to the "normal" direction, and came to include situated accounts of invariance when they noticed that the center of rotation, and the shape (including its size) was invariant under the transformation. By exploring rotations further, they recognized that the points of the preimage and image are equidistant from the center of rotation.3

* 38 * Although omitted due to space constraints, it is worth mentioning that for scaling (dilation) tasks, the students asserted that the shape grows bigger or smaller, that the coordinates of the shape change not additively but through multiplication (a "scaling factor" in GnG parlance) and recognized that the position and size of the final figure depend on both the location of the pivot (point of invariance) and the scaling factor.
This study showed that students progressed from defining the domain of transformation as selected points of the figure (e.g., "the points are changing to a (7, 5) and a (11, 5)") to later include all points of the figure (e.g., "I think all the points [of the figure] will change") and (possibly) even including all the points on plane as a domain by referring to points outside of the figure being transformed (e.g., "Because everything rotates around it[the pivot]").

GnG acted as a constructionist medium in that it engaged the users in activity that facilitated the growth of their initial naïve ideas about GT. Trying to "match" the shape in GnG acted as a window to the embedded mathematical reasoning, giving students iterative opportunities to generate new experience and to modify previous conceptions. Seymour Papert (1980) talked of "de-bugging" as the process through which the children search for what they made wrong and try to find a way to fix it. The immediate visual feedback provided by the animation environment played a significant role in this process: students routinely used the GnG visual feedback to modify their conjectures to match the shapes and form generalizations.

The features (including constraints) of the tools and of associated activities prompted the students to adapt their problem-solving strategies and their language. For instance, students recognized that they needed to use the negative sign to move their shape "backwards" or "downwards" during translation, as well as to perform a clockwise rotation.

While working with computer software, pupils adapt their strategies to its constraints and functioning mode, and the new meanings are generated by this continuous process of adaptation, thus constructing new knowledge.

The work reported here suggests that by providing students with opportunities to investigate relationships between transformations and the geometric space in which those transformations are enacted, GnG has the potential to support dynamically the advancement of students’ thinking of GT. As Andrea Dessa argued,

“This is the idea of microworlds, constructing artificial realities that intersect enough with students’ ideas that they can immediately begin to manipulate them, but whose ‘deep structure,’ if you like, leads inevitably beyond those initial perceptions and conceptions.”

Acknowledgments

This work was supported by the Fulbright Commission of the U.S. Department of State (awarded to Nicole Panorkou). We thank Jere Confrey at North Carolina State University and Douglas Platt at Montclair State University, whose work and feedback enabled us to make this research possible.

Received: 19 February 2015
Accepted: 1 May 2015

http://www.univie.ac.at/constructivism/journal/10/3/338.panorkou
Documenting the Learning Process from a Constructionist Perspective

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> Upshot • This commentary assumes a constructionist perspective to discuss the choice of methods, conclusions and design goals that Panorkou and Maloney make in their study of students’ activities with the Graph ‘n Glyphs microworld.

How do constructionists measure learning?

« 1 » Constructionism has been cast as both a theory of learning with artefacts and a theory for designing artefacts along with accompanying sequences (cf. Kynigos 2015). In this commentary, I first examine some of the main assumptions of this theory, and then discuss how they apply to the research on learning and design described in the study conducted by Nicole Panorkou and Alan Maloney.

« 2 » Seymour Papert claims that constructionism was purposefully named to draw attention to the similarities and areas of departure with constructivism (for a description of radical constructivism over the past forty years, see Riegler & Steffe 2014). In particular, Papert (1992) argues that both theories are based on the belief that knowing is a personal, constructive act. Both the teacher and the student create their own constructions of what is heard and discussed through their own experiential lenses. The implication of this assumption about learning is that knowledge cannot simply be conveyed in ready-made form from one person to another, nor can learning be assumed to be similar among people, even if they are taking part in the same conversation.

« 3 » Papert states that the point of departure between the two theories lies in constructivism’s apparent privileging of abstract thinking. This conclusion is based on his observations that teachers chose to use Jean Piaget’s theory of stages as a way to gauge and guide age-appropriate teaching. Papert claims that, especially with regard to young children, the result of the stage theory is that schools have a “…perverse commitment to moving as quickly as possible from the concrete to the abstract thus spending minimal time where the most important work is to be done” (Papert 1993: 143). He also states that the use of tests to measure abstract learning does not represent the valuable learning-in-action that comes from play and situated engagement.

« 4 » The question that this fork in epistemology highlights is: How should educational researchers document learning? Panorkou and Maloney argue that the use of the teaching experiment methodology provides the best way to probe students’ motivations as they are constructing in the “physical world,” such as making a sand castle or a Lego house, or playing in a microworld such as Graph ‘n Glyphs (GnG). The challenge with this type of work is that the array of possible meanings and interpretations is almost limitless, thus making it difficult for researchers to substantiate claims of any particular or “abstracted” learning occurring, or that the same learning could have occurred among the individual conversants.

« 5 » In their article, Panorkou and Maloney provide short snippets of conversations that serve as examples of how two of the students acted with each other and with the microworld to make sense of their activities and reach their goals. In my view, the chosen examples are poignant and very provocative. However, as noted in the proviso above, I am not sure that the examples that are shared support some of the authors’ conclusions regarding what each of the two students “learned.” For example, in Excerpt 2, the students decide to combine vertical and horizontal translations in one step. This is an excellent and situated idea that would be a natural action when working in the physical world. However, the authors’ conclusion that this decision “[…] may be considered illustrative of a situated version of defining a translation vector as a linear combination of the individual component vectors […]” makes the set of vectors linearly dependent” (§23) seems unsubstantiated. That is, the data provided does not present compelling evidence that either of the fourth grade boys had constructed any notion of linear dependence, or even how the combining of vertical and horizontal components relates to linear combinations.

« 6 » A second example of a meaning-making exchange that was fascinating in its own right but not sufficiently documented to substantiate generalized learning occurs
The data suggest that perhaps Nate did conceptualize this notion of the center of rotation, but there is no indication that Ben had assimilated the Earth rotation analogy, let alone constructed a situated abstraction of it that would relate to the center of rotation being placed either inside or outside the object.

Papert’s focus on what students do say rather than what students don’t understand suggests that Nate’s analogy deserves further attention. Using the Access Framework of Understanding (Perkins et al. 1995), we can consider his understanding on the outside in order to make inferences about his understanding on the inside. His explanation demonstrates three key characteristics of understanding performance:

1 - He offers explanations to Ben that explain what is going on in the microworld in situated terms;
2 - He articulates a rich relational knowledge by bringing in the analogies of both forms of Earth rotation; and
3 - He displays a revisable and extensible web of explanation by coming back to his original thinking from Excerpt 6 in Excerpt 9 (which apparently took place one week later).

Thus, one could argue that he has constructed mental connections, but there is no evidence to suggest that the other student (Ben) did the same. How do constructionists design for learning?

8 - When designing microworlds to support students’ play, designers consider the affordances of the media. One would assume that the GnG software was designed to exceed the shortcomings of the “table tasks” described in the article. Certainly, both media can support the students’ generalization that shape and size are preserved under translations and rotations. But, ironically, they had to work with the program to assure that students viewed translations as actions on the preimage in order to dispel the idea that the preimage and the image were different objects. Other affordances of the program were more clearly elaborated. For example, one of the program’s clear benefits is its ability to execute transformations based on input parameters such as length and direction of vectors or degrees of rotation. This feature enabled the students to look inside the “black box” of transformations in order to accomplish their goals, and, in so-doing, make meaning of how the feature worked.

9 - Using Papert’s contention that microworlds allow students to “something else” instead of math (which I take to mean what students would consider performing memorized algorithms that relate to concepts rather than working on a physical-world constructions such as building Lego bricks), my first design question is: What was the students’ goal? What was the “other activity” in which the students were imagining that they were engaging? The authors briefly mention that the grant that supported this work was designed to engage students in the creation of animations. If this was the case and the larger motivation, then were they setting their own goals, or were they working on tasks that the interviewers provided? So, we might ask, was the original study designed to focus on students’ learning of abstract concepts regarding transformation geometry in the context of animation? If so, it would have been fascinating to see whether their situated activities resulted in the creation of animations. And, in particular, what aspects of their activity within the microworld affordance system enabled the students to become bricoleurs (as quoted by Papert, who was describing the work of Claude Lévi-Strauss) by acting and revising their situated activity using the tools at hand.

10 - A second, related question is: Why was the timeline feature detailed in the introduction, but not featured in the students’ activity? Was this feature designed to be an affordance of the software that could support multiple steps in one execution, or was it part of the larger goal of creating animations?

In summary, Panorkou and Malden provide some interesting observations describing students’ situated activity and their discussions to make sense of it from a constructionist perspective. Using the students’ actions and answers as the unit of analysis provided great insight into how they were using some of the affordances of the software and making sense of their actions (although not learning the same things). Thus, for me, the value of this article lies in its utility to support further design of software and instructional sequences. The work also provides a starting point for these and other researchers to replicate and build on the sequence and students’ responses in order to propose a fully developed model to support students’ learning of transformational geometry – perhaps within the broader context of learning animation. The goal would be to create research that contains what Alan Schoenfeld (2000) claims are standards for research models in mathematics education: descriptive power, explanatory power, scope, predictive power, rigor and specificity, falsifiability, replicability, and triangulation.

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Received: 8 June 2015
Accepted: 20 June 2015

http://www.univie.ac.at/constructivism/journal/10/3/338.panorkou
Reasoning in a Dynamic Animation Environment
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> Upshot • Parnorkou and Maloney describe how a dynamic animation environment, Graphs ‘n Glyphs, supported fourth-grade students’ understandings of translations and rotations. Two elements were critical in their teaching experiment: the design of the software and tasks. This commentary focuses on the decisions that they made and possible implications they had for students’ reasoning.

1 The importance of geometric transformations in developing students’ understandings of geometry and function has been acknowledged for some time and this topic has been included in the K-12 mathematics curriculum in the United States for several decades (Coxford 1991; National Council of Teachers of Mathematics 1989, 2000; Sinclair 2008). In addition, the study of geometric transformations is amenable to the use of non-technological and technological tools (Coxford 1991; National Council of Teachers of Mathematics 2000). Nicole Parnorkou and Alan Maloney share interesting insights from their research about the ways in which a dynamic animation environment, Graphs ‘n Glyphs (GnG), supported fourth-grade students’ understandings of translations and rotations. Two elements were critical in their teaching experiment: the design of the software program and the design of the tasks. My commentary will highlight important decisions the researchers made in the design of the software and tasks and discuss possible implications these had for students’ reasoning.

Software design

2 When designing software for geometric transformations, one must carefully consider the ways in which teachers and students interact with the tool, the information the tool provides, modifications teachers and students can make, and a history of actions and how they are displayed (Underwood et al. 2005). In this regard, GnG does a great job, displaying a history with the timeline. The coordinate grid background is another critical and important feature. With the coordinate grid, students build on their experiences with number lines for adding and subtracting to consider horizontal, vertical, and, finally, diagonal translations. It was clear that students were able to use the grid to perform translations and rotations. However, it was not clear how this interface scaffolds students as they transition from thinking about translations performed in a vertical and horizontal direction to thinking about translations defined by a vector.

3 To examine how other software programs represent vectors, Cabri Geometry II Plus, Geogebra, and The Geometer’s Sketchpad were reviewed. Cabri Geometry II Plus requires the selection of the object and then the selection of the vector that defines the translation.

4 Geogebra requires users to interact with the software in a similar way as Cabri. The Geometer’s Sketchpad allows one to translate by a polar, rectangular, or marked vector (Figure 1).

5 What is interesting with this interface is that students are able to enter a negative value for the horizontal or vertical fixed distance to move left or down. Although the GnG interface is most closely related to The Geometer’s Sketchpad, rather than using distance in centimeters to specify the horizontal and vertical components of the vector, units determined by the coordinate plane are used. This coordination is nice and builds on students’ understandings. However, despite the claims of Parnorkou and Maloney, it is not clear what students will come to understand about vectors as having magnitude and direction, or what they will understand about distance when negative values are entered. For example, in excerpt 1 of students’ work with the tool, the researcher asked students to move a square eight spaces to the left. The student stated that, “minus means go down” but he entered -8 to move left, not down. He seemed to understand “go down” as “back or take away.” The use of the negative sign in this manner could be problematic and may not support students’ understanding of the magnitude or direction of a translation vector. Negative values are not used to describe magnitude nor are they used to describe direction. Perhaps a task could be designed that places vectors on a coordinate grid to develop students’ understandings of translation vectors. Several comments about the design of tasks are provided.

Representing vectors

6 To build on students’ understanding of translations as moving in a vertical and horizontal direction, a vector described with coordinates for its head and tail might be introduced (Figure 2).

7 This representation is related to the number line and could move students to thinking about direction up, down, left, and right without using the negative sign to refer to the left and right direction. Another option would be for the dialog box to have four quadrants to allow students to move down and left.

Selection of objects

8 It is also important to note that the objects students are provided to transform are important to consider. Students may
not notice anything has changed if they are provided with a square to rotate 180 degrees about its center or reflect about a vertical or horizontal mirror line. This applies to other objects that have symmetry. The dog and fish provided in the GnG environment were likely more helpful to students than the star. It is unclear why these images were not selected to be more “real-life” given the animation environment context.

**Referent points**

« 9 » It is also imperative that students become familiar with the language of preimage and image points and that students are provided with corresponding points. It was clear that students learned that the “points had to match.” Excerpt 3 shows how students were able to match the two stars, but had difficulty matching the two houses. It is important to note that point A was marked on the preimage and point B on the image was not marked. Students might have assumed point B was located where it was labeled. It is also interesting to note that the preimage (the house on the right) included its own axis but this was not included on the house on the left. These differences may have contributed to students’ difficulty. It is unclear whether points A and B were intended to be corresponding preimage and image points or perhaps they were intended to be labels on the objects. This is a critical distinction that would need to be discussed with students. Also noteworthy is that the sequence of actions students performed on the house task might be reflective of a reactive strategy, rather than a proactive strategy they seemed to use with the star task (Hollebrands 2007). Perhaps the difference was related to the direction of the translation, the object provided, or the interactions the students had with the researcher.

**Summary**

« 10 » Overall, the research report discusses interesting ways students reasoned about translations and rotations. It is important to consider what students notice and observe and how these may be related to the design of the software and tasks, and their interactions with each other and the researcher.
activated a brief discussion about the nature of minus in which one student said that minus is anti and that “[…] anti means ‘not’” (§31). So I do not think this is a weakness in the design, and in fact one of the strengths of the current design is that it encourages thinking about coordinates in a way that body syntonicity does not necessarily do. A main distinction between Logo turtles and geometric shapes is that geometric shapes consist of many points, whereas Logo turtles are one point each. But since the study showed that the two learners were able to perform rather sophisticated rotation, even around pivot points that were outside of the shape, I do wonder: Would have taking a body syntonic approach to designing these primitives activated other knowledge in students? Would it have affected the way in which the authors’ GT tasks would be designed? Has a body syntonic approach a role in GT learning?

Author’s Response: Planting Seeds of Mathematical Abstraction
Nicole Panorkou & Alan Maloney

> Upshot • We consider that elementary students’ situated activities with geometric transformations and animation contain the seeds of complex, and eventually, mathematically generalizable and abstract reasoning. Further studies can explore such technologically-based activities’ potential as building blocks for flexible, creative, and formalized knowledge.

1 We note that a common theme of the commentaries on our article is how we measure, capture, or examine learning in constructionism. In our article, we describe students’ learning of geometric transformations (GT) by studying the changes of their thinking in terms of situated abstractions (Noss & Hoyles 1996). Abstract mathematical ideas of GT were embedded in the tasks and the tools offered to students, and our study was interested in finding how students articulated experiences of GT in the context of graphically-based figures and animation, and developed more abstract or general mathematical reasoning related to that graphical and animation activity.

2 The design of Graphs ’n Glyphs (GnG) was intended to engage students in fun and productive work in an environment with which students were already familiar – even immersed in – while revealing, and supporting use of, the underlying mathematics of animation. The software was designed for situated activity – computer-based animation – in which increasingly abstracted mathematical/geometrical reasoning become both accessible to students and necessary for sense-making and designing. Students would also build relevant skills: the tool incorporated features of professional animation software, such as dual coordinate planes (not highlighted in this study) and the animation sequencer. Most importantly, the software and associated tasks require students routinely to make direct bidirectional connections between animation design/behavior and more abstracted mathematical reasoning.

3 The students in this study engaged with a combination of constructs earlier than is typical in American elementary education. They gained experience in acting on geometric objects on a coordinate plane, constructed their own descriptions to distinguish among transformation types, and began to adopt precise language to characterize transformations. We consider students’ situated abstractions as having the potential to grow into something more complex and, eventually, mathematically abstract:

4 The commentaries questioned whether students “understood” the abstract ideas we describe (Janet Bowers and Karen Hollebrands), and suggested that there is no indication that the two students had the same understandings about GT (Bowers). We appreciate the opportunity to clarify. In identifying the connections to abstract mathematics, we did not expect the young students to learn in any detail the mathematical notions identified. We intended instead to suggest the potential for their articulations to be leveraged as situated accounts of mathematical experiences, which could be recognized by researchers or teachers enculturated in those mathematical ideas. Also, our goal was not to suggest that all the students had the same understandings. So, for instance, we did not intend to claim that these young students understand translations to be based on vectors or other formal aspects of transformations, but rather to suggest possible connections between the students’ articulations and the mathematical constructs. It remains a matter of conjecture whether such experiences might subsequently be building blocks for such formalized knowledge, but the students’ work provides an expanded vision of what elementary-age students are capable of learning about GT when tasks and software give them the opportunities to do so.

5 The nature of such teaching experiments, especially using an innovation such as a technological tool, is to engineer the conditions of learning (the learning ecology) and explore the changes in student learning that result – through student work products, discourse, and classroom interac-
tions. Our interpretation of potential mathematical abstraction (e.g., the abstractions we connected to Nate’s analogy of different positions of the center of rotation, relative to an object and to the Earth’s rotation and orbit) would perhaps be more accurately represented as a conjecture or “humble theory” (Cobb et al. 2003; Confrey & Maloney 2015) that can now be incorporated into instructional goals as a basis of a subsequent teaching experiment.

"6" Three different teaching experiments using GnG (this study, Confrey et al. 2010, and one not yet published) have now seen students (fourth through eighth grades) construct figures and animations while developing and using mathematical language and concepts that are rooted in the activities of transformations. The aforementioned bidirectionality between situated context and more abstracted mathematical/geometrical reasoning is a consistent feature of students’ work with the tool and tasks, suggesting that by linking the situated context with the geometric space in which transformations are enacted, GnG and tasks dynamically support the advancement of students’ thinking about GT.

"7" Arthur Nijholt raised the question of designing microworlds that are inspiring and fun learning environments while eliciting externalized thinking (an explicit goal of GnG). GnG mimics some aspects of game environments, setting challenges for students within a microworld whose rules are readily discerned, not overly restrictive, novel for mathematics instructional contexts, and closely related to the experts’ tools. And it has avoided automated or drag-and-drop tools, which would obscure the underlying mathematical basis of the animations.

"8" Bowers suggested more creative use of the animation component of the software. In the current study, we did not extensively employ development of animation sequences (the sequencer was designed “to support multiple steps in one execution” as well as “part of the larger goal of learning animation”), but this would be a focus of a more extended study. We note that in a previous study (Confrey et al. 2010), middle-grade students created highly complex and inventive animations, such as schools of fish moving in the sea and a motorcycle doing “wheelies,” and contributed to design improvement in the software as well. The richness of transformation sequences and student collaboration is practically boundless and highly engaging for the students.

"9" The commenters suggested several modifications, which offer potential strengthening of connections between the animation context and explicit geometrical and numerical-operational abstraction. We are considering: a vector tool to support students to generalize diagonal translations; on-demand availability of all four quadrants on local and global coordinate planes (students identify the need for negative coordinate values) and to support (per de Hollebrande) students’ making meaning for, and distinguishing between, negative values for direction and position; more “real-life” images; and enriched tools for creating new shapes.

"10" By exploring transformations, elementary students can learn foundational, if non-formal, versions of GT concepts, and make connections to related geometric concepts (properties of shapes, mapping, magnitude, direction, ratio, and negative numbers). We see these seeds for development of such notions for later years of schooling as similar to Seymour Papert’s (1980) “gears” of his childhood, early experiences with the gearbox and the differential that served as models that set the stage for rapidly making sense of equations:

**I found particular preference in such sequences as the differential gear, which does not follow a simple linear chain of causality since the motion in the transmission shaft can be distributed in many different ways to the two wheels depending on what resistance they encounter [...]. I saw multiplication tables as gears, and my first brush with equations in two variables (e.g., \(3x + 4y = 10\)) immediately evoked the differential. By the time I had made a mental gear model of the relation between \(x\) and \(y\), figuring how many teeth each gear needed, the equation had become a comfortable friend.** (Papert 1980: vi–vii)

Received: 20 June 2015
Accepted: 26 June 2015

Combined References


http://www.univie.ac.at/constructivism/journal/10/3/338.panorkou
Educational Research Experiments in Constructivism


Constructionism and Deconstructionism

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> Context • There is a movement to change education so that it is adequate to social expectations and uses the full potential of technology. However, there has been no significant breakthrough in this area and there is no clear evidence why. > Problem • A potential issue explaining why education falls behind is the way educators focus on education. There is a possibility that a significant step in the learning process is routinely neglected. > Method • Two different approaches to using IT in education are tested in two different environments: a university level course based on constructionism and IBL projects for secondary school students. > Results • It is possible to apply constructionism in education, but there are still problems. They are not related to how students construct knowledge, but how they deconstruct knowledge. > Implications • The most significant problem of deconstruction is that it requires creative skills. This makes it very difficult to formalize it and to provide effective recommendations for its application. > Constructivist Content • Deconstruction is a prerequisite of construction, thus deconstructionism deserves more attention and study. A proper application of deconstructionism will make it possible to reconstruct education in a way that is impossible with the current approaches. > Key words • Deconstructionism, constructionism, future of education, inquiry-based learning.

Constructivism and constructionism

> 1 » Constructivism in education is a philosophy that advocates the construction of knowledge through real-life or real-life-like experiments fostering learning. The role of the teacher is not to transmit or to impose knowledge, but to guide the learner through his personal journey in learning.

> 2 » The earliest examples of constructivism in education were proposed by John Dewey and Maria Montessori. Dewey (1910) described thinking as a natural act that should be supported by an encouraging environment that is rather different from the monotonous uniformity of classrooms and textbooks. An important factor for the development of creative thinking is the curiosity that leads to exploration. According to Montessori, education starts from birth and “[t]he child must not be considered as he is today […] He must be considered in his power of potential man” (Montessori 2001: 3). She built unique learning environments that are considerate of the student’s physiological and psychological age.

> 3 » A significant contribution to constructivism was made by Jean Piaget. He saw learning as a continuous process where a student assimilates knowledge entities into meaningful knowledge constructs. Constructivism, as described by Piaget, is focused on the mental models of the world. This theory was further extended by Seymour Papert in a way that applies it to practical construction. Papert called this “constructionism.” The main concept is that constructing tangible artefacts helps the construction of mental understanding of the world. Papert proposed an extensive use of IT in the classroom that supports another important aspect of constructionism, namely, that constructing entities is public in the sense that they are observable by others. More importantly, the process of construction is also public and this makes learning more effective and sustainable.

Constructionism in education

Constructionism at university level

> 4 » The concepts of constructionism have been applied to education and the results are promising. Several courses introduced by the Faculty of Mathematics and Informatics at Sofia University are focused on educational software and real-time computer animation (Boytchev 2007). In these courses, students learn the basic skills and approaches of building complex constructs out of a small set of elements. One of these courses is Geometry of Motion – a multi-disciplinary course spanning mathematics, physics and computer science. In it, students become familiar with the fundamentals of geometry, how it is used to describe physical motion and how to implement this as an animation.

> 5 » When Geometry of Motion started in 2007, the computer science component was merely a demonstration of computer animations. Most of the time was spent on discussions about how they had been built. We used a public collection of virtual mechanisms (Boytchev, Sendova & Kovatcheva 2011). However, they were standalone programs that were hard to use as learning objects.

> 6 » In 2010 I developed a library called Mecho (Mechanical Objects). Students could use it to construct their own devices (Boytchev 2013a). Since then, new versions of Mecho have been released annually, the last one being completed in March 2014. This version is a result of the research project DFNI-O01/12, financially supported by the Bulgarian Science Fund of the Ministry of Education and Science. The project addresses contemporary programming languages, environments and technologies and their application in the development of software specialists.

> 7 » The design of Mecho follows the major ideas of constructionism. It provides a tool for expressing creativity through
public construction of virtual mechanisms. Mecho represents virtual mechanisms as structures with a well-defined hierarchy. There are configurable elements for the basic mechanical components, such as beams and gears. They are used to build simple devices that can be arranged in complex machines. An example of the structural hierarchy is demonstrated in Figure 1. The left image shows individual mechanical components; the middle one displays a virtual device drawing the Lemniscate of Bernoulli; and the last one is a machine exploring chained symmetries.

The making of a virtual device is an optional activity for the students. It is up to them to engage in such activity or to ignore it. As a result, very few students have volunteered to build devices. Table 1 shows the number of students for each academic year. During the first three years of Mecho, about 93% of the students avoided it.

After a detailed analysis of the first three years of Mecho, I identified the key elements that had prevented students from becoming motivated to use it:

- **The learning barrier:** The allocated time for the computer science component of the course was 15 academic hours. This was insufficient to introduce a new programming language (i.e., Logo), to demonstrate motion implementations, to present Mecho and to teach how devices are made. In 2013 I addressed this issue by rewriting Mecho and all teaching materials in C++, a language well-known by the students.

- **The conceptual barrier:** Creating interactive 3D projects is cumbersome, especially if students deal with visualisation and rendering issues. This barrier was resolved by redesigning Mecho so that all activities, such as frame generation and mouse-based navigation, happen “automatically.” In this way students focused on the virtual mechanism.

- **The mathematical barrier:** Although students had studied analytical geometry, they still had no practical sense of 3D motion. It was unexpectedly difficult for them to express orientation in 3D space via Euler angles. This

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**Table 1** • Number of students working on Mecho projects.

<table>
<thead>
<tr>
<th>Year</th>
<th>Major event</th>
<th>Number of students Enrolled</th>
<th>Working on projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007–2008</td>
<td>No projects, just demonstrations</td>
<td>15–20</td>
<td>N/A</td>
</tr>
<tr>
<td>2008–2009</td>
<td></td>
<td>15–20</td>
<td></td>
</tr>
<tr>
<td>2009–2010</td>
<td>The course was not offered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011–2012</td>
<td></td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>2012–2013</td>
<td></td>
<td>36</td>
<td>2</td>
</tr>
<tr>
<td>2013–2014</td>
<td>Reimplementation of Mecho in C++</td>
<td>36</td>
<td>20</td>
</tr>
<tr>
<td>2014–2015</td>
<td></td>
<td>57</td>
<td>Course is ongoing</td>
</tr>
</tbody>
</table>

**Figure 1** • A virtual component (left), a device (middle) and a machine (right).
observation convinced me to exchange mathematical efficiency with user friendliness. I modified Mecho to use comprehensible representations. For example, I implemented 3D orientation by 4 angles instead of the optimal 3 Euler angles.

- The procedural barrier: The evaluation of projects considered 25 criteria. Students were introduced upfront to these criteria, but they still experienced problems complying with them. I observed that students were trying to address many criteria at the same time. As a result, they failed to comply with most of them. In 2013 I clustered criteria into five levels and students had to fulfill the levels in a predefined order. The levels represented compulsory criteria, procedural experience, visual experience, hardware experience and software experience (see Figure 2).

10 Our solution for the four barriers made the construction of devices much easier. The number of students almost doubled and their engagement with projects increased eight-fold: from 7% to 56% (see Table 1).

11 The first projects using the redesigned Mecho were delivered in June 2014. Figure 3 shows snapshots of three virtual mechanisms (re-)created by students.
Constructionism at secondary school level

« 12 » Inquiry-based learning (IBL) is a concept closely related to constructionism. In IBL we learn by asking questions and finding answers, rather than by listening to a stream of pre-digested facts. IBL is one of the approaches to implementing constructionism in education and it is recognized as such by institutions at different scales. This section presents software developed for two complementing IBL projects: weSPOT (EC FP7 Programme in Technology Enhanced Learning) and The Role of IT in the Application of IBL in Science Education (Sofia University Science Fund).

« 13 » The goal of weSPOT is to create software tools and know-how for personalization of the IBL environment and management of IBL activities. The project developed a detailed IBL model of six interconnected phases and over 40 components. They are shown in Figure 4 and discussed in Protopsaltis et al. (2014). The hypothesis is that students become researchers and scientists by asking curiosity-driven questions to obtain structured knowledge/context of science concepts. Students are expected to gain skills for effective research, collaboration and creativity.

« 14 » The goal of the second project was to conduct research on the role of IBL in education. It adapted weSPOT’s results and focused on science experiments, individualization of education and social collaboration. Several pilot experiments were conducted as a competition between three grade-6 classes. The topic of the competition was “My classroom – The most energy efficient!” The task was to measure temperature variations, weather conditions and the classroom status (such as opened windows, doors, air conditioners, number of people, etc.) Each class produced a report including analysis of factors affecting energy consumption. The reports contained suggestions and ideas for reducing the amount of lost energy. The pilot started on 17 November 2012 – the first day of the European Week for Waste Reduction and finished on 5 June 2013 – World Environment Day.

« 15 » During the first year, the students collected data for three months – see Table 2 and Figure 5. More details about this phase...
of the project are described in Stefanov, Nikolova & Stefanova (2013) and Stefanov et al. (2013).

«16» The duration of the data collection was demotivatingly long for 6-graders. It was difficult to keep the students interested in the competition. From the IBL point of view, there were two main problems with this kind of pilot test. It was impossible to repeat the same experiment twice. It was also impossible to change the initial configuration of an experiment and test how this would affect the outcome.

«17» For the second year of the project, we decided to provide an alternative approach and developed the Virtual Classroom (Boytchev et al. 2014). This is software containing a non-interactive simulation (see Figure 6) and a standalone interactive 3D application (see Figure 7). The implementation was based on decisions that were initially considered risky.

«18» The first risky decision was to make a continuous simulation. There were no means to start or stop the virtual classroom. It was running even when the students were setting the parameters of their experiments. The second risky decision was to make unrestricted simulation. This is the ability to set unnatural initial conditions, such as snowing at 40°C. In such a case, the air temperature would smoothly go down until the physical model reached equilibrium. The main feature of the simulation mechanisms was that it only managed transfer of energy in small quantities towards equilibrium.

«19» Continuous and unrestricted simulation contributed to a better simulation, closer to the actual world, where students cannot control the fabrics of observed phenomena.

«20» To support the inquiry process, the Virtual Classroom was distributed without any documentation. Thus, students and teachers had to find by themselves all the software's features: from navigation to conducting experiments. There was no description of the simulation mechanism. For example, students conducted experiments to find whether the number of people in the classroom affects the air temperature.

«21» The pilots with the 6-graders were video-recorded, and snapshots of the recordings are presented in Figure 8. The analysis of the recordings showed that the software provoked inquiry learning and active constructionism. Every student worked at his or her own pace while gaining scientific skill.

«22» The pilots were conducted in the spirit of constructionism. Students learned by constructing public entities. The process of construction was also public. While observing the progress of their classmates the students soon started to exchange ideas. One interesting and unplanned observation was how students experienced the scientific importance of details. Several students conducted “equivalent” experiments, but got opposite results because of subtle differences in the initial conditions. This experience was quite valuable. It helped gain the skill of distinguishing important from unimportant factors.

Deconstructionism in education

Phases of constructing knowledge

«23» The experience with university and secondary school students showed that it is not straightforward to utilize constructionism. Although we created different tools to support this application, students still experienced problems.

«24» The process of learning through construction can be split in two phases – deconstruction and construction, shown in Figure 9. I use the word deconstruction in the sense of decomposing or breaking down something into reusable entities. In contrast, the meaning of destruction would be to destroy something. The left image in Figure 9
represents some knowledge. The first phase of learning is to decompose this knowledge into smaller yet meaningful entities for the learner. These entities are used as building blocks to construct the personal knowledge, which is not necessarily the same as the original knowledge. There is a third phase where new knowledge is created by rearranging the entities in another way.

Figure 9 • Phases of learning through deconstruction and construction.

**Figure 3** differs from the traditional implementations of harmonographs, and was in-part realized by the students. For example, the left-most mechanism in Figure 3 presents as an outcome of fundamental functional decompositions based on mathematical functions. This deconstruction is hard for many students. They lack the skills to see (or to imagine) how a composite animation could be represented as an outcome of fundamental functions.

**Pattern recognition**

This is the ability to identify meaningful entities in an otherwise chaotic-appearing texture. Patterns are not only visual. They could also be patterns of algorithms, patterns of methodology, patterns of approaches and patterns of behaviour. A proper identification of patterns contributes to successful construction. The manifesta-
Deconstruction outside education

People are prone to deconstruction. It is not an artificial activity introduced through and for learning only. Traces of deconstruction can be observed in many situations beyond the traditional educational context. Deconstruction is actually a part of our lives. All the following examples are deconstructions:

- A child breaking a favourite toy just from curiosity to see what is inside
- A person trying to distinguish the ingredients of a meal by the aroma of its spices
- A scientist reverse-engineering a biological mechanism.

Apparently, deconstruction is not just something that happens sporadically through our lives. It is also a major scientific arsenal. For example, the deconstruction of mathematics leads to the “invention” of its fundamental axioms. It is not a one-way route. Different mathematical sciences, especially the geometries, have been successfully deconstructed into different sets of axioms.

Once we have the axioms, we can construct back the corresponding mathematic.

With a more global scope, the understanding of nature goes first through its deconstruction into sciences such as physics, biology, chemistry and astronomy. This deconstruction phase is vital. Without it we will be overwhelmed by the complexity of nature. The construction phase is already happening. It is the reverse process of merging back different sciences and building multidisciplinary relations, such as astrobiology and medical informatics. The construction phase will end when all sciences merge coherently into one.

Constructionism and deconstructionism

I define deconstructionism as a distinct perspective on the same objects and processes that are requisites for the constructionism. Constructionism is focused on the personal construction of ideas and relations through the construction of real knowledge, skills and deconstruction entities in the university and secondary school experiences.

<table>
<thead>
<tr>
<th>Knowledge to be deconstructed and then constructed</th>
<th>University experience with Mecho</th>
<th>Secondary school experience with Virtual Classroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expressing complex motion with a limited set of functions</td>
<td>Finding questions leading to scientific approaches in finding answers</td>
<td></td>
</tr>
<tr>
<td>Mapping mechanical linkage to a geometrical curve and vice versa</td>
<td>Conducting experiments in a dynamic environment</td>
<td></td>
</tr>
<tr>
<td>Transforming abstract mathematical linkage to a physically possible linkage</td>
<td>Studying the behaviour of unknown complex systems</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Skills supporting deconstruction</th>
<th>University experience with Mecho</th>
<th>Secondary school experience with Virtual Classroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognition of graphs of functions</td>
<td>Observation of real-life and simulated phenomena</td>
<td></td>
</tr>
<tr>
<td>Decomposition of composite functions into fundamental functions</td>
<td>Extracting optimal set of parameters capturing observed behaviour</td>
<td></td>
</tr>
<tr>
<td>Approximation of functions via simpler functions</td>
<td>Relating environmental changes to system configuration and vice versa</td>
<td></td>
</tr>
<tr>
<td>Solutions to mechanical collisions</td>
<td>Eliminating false positives and false negatives</td>
<td></td>
</tr>
<tr>
<td>Reversing kinematic</td>
<td>Conducting different experiments to verify a single hypothesis</td>
<td></td>
</tr>
<tr>
<td>Expressing motion with higher degree of freedom as a composition of several lower degree motions</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Entities created by deconstruction</th>
<th>University experience with Mecho</th>
<th>Secondary school experience with Virtual Classroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental mathematical functions (e.g., sine and absolute value)</td>
<td>External factors affecting energy consumption (e.g., temperature, clouds)</td>
<td></td>
</tr>
<tr>
<td>Mathematical operations (e.g., vector addition, linear combination)</td>
<td>Internal factors affecting energy consumption (e.g., door, air conditioning)</td>
<td></td>
</tr>
<tr>
<td>Basic mechanical components (e.g., beams, rails, gears)</td>
<td>Mathematical relations (e.g., energy consumption vs temperature difference)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Possible artefacts of creativity</th>
<th>University experience with Mecho</th>
<th>Secondary school experience with Virtual Classroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>A mechanism that is functionally equivalent to existing ones but uses fewer mechanical parts</td>
<td>An algorithm for smart control of energy consumption in buildings, based on precise sensing and forecast of weather</td>
<td></td>
</tr>
<tr>
<td>Know-how about mechanisms with motion that can be expressed by 3rd degree polynomial functions</td>
<td>A simple formula for quick approximation of power requirements in a building</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 • Knowledge, skills and deconstruction entities in the university and secondary school experiences.
life artefacts. Deconstructionism is focused on the personal understanding of ideas and relations through the public deconstruction of real-life artefacts.

Similarly to the relation between constructivism and constructionism, deconstructionism is about the mental private decomposition of ideas and relations, while deconstructionism is about the deconstruction of a tangible artefact or about the public deconstruction of a concept. In this sense, the sequence of phases as pictured in Figure 9 is not to be considered sequential or linear. In fact, the deconstruction phase is repeated several times until the initial knowledge is decomposed into proper ingredients that can be used for reconstruction of the personal knowledge. This may take several attempts, as indicated in Figure 10.

The deconstruction phase is not deterministic, just as the construction phase is not deterministic. Problems in learning due to excess cognitive load or a cognitive barrier occur predominantly in the deconstruction phase. When students cannot relate a new concept to their previous knowledge, they actually fail to decompose that new knowledge and get stuck. This is the focus of the deconstructionism.

The future of education

Deconstruction of education

In an interview for New Scientist, Noam Chomsky says "If you're teaching today what you were teaching five years ago, either the field is dead or you are" (Lawton 2012). Although he is referring to linguistics, the same applies for all domains in education. The digital era is having a tremendous impact on how we learn. People have already created digital content that exceeds the capacity of available storage. Modern technology challenges the traditional pillars of the educational model: student, teacher, textbook and school. The average digital weight (volume of created digital content) of a student is overtaking the digital weights of the teacher and the textbook combined. The accessibility of digital content is displacing the school as a main source of knowledge. It questions the very nature of the traditional school and textbook.

For centuries, education was changing incrementally. Today it cannot cope with the exponential development of technology. There are two possible paths: either education distances itself from technology, or embraces it. Clearly, technology and education cannot be separated. The attempts to restore the balance between them by mere reconstruction of education do not produce sustainable results. The introduction of ICT in the classroom is unable to synchronize education and technology. An alternative approach is to deconstruct education into its fundamental components, then to build a conceptually new education. Thus, deconstructionism could become the major player in reshaping how people teach and learn. Deconstructionism in education is hard to achieve. Deconstructionism of education will be much harder.

Factors to consider

Digitality

Several factors may affect the future of education and digitality is one of them. The word digital has two meanings related to education. The first one is finger. It is what education was for centuries – learning by hands-on activities. The other meaning is related to numbers. It is what education is trying to become nowadays – learning by manipulation of virtual entities. Unfortunately, the numerically digital education is becoming dominant and is dislodging some of the best practices in the “fingerly” digital education (Boytchev 2013b). Fortunately, the advances in technology make it possible to merge both digital educations.

Ubiquity

There is a trend of promoting ubiquitous learning (u-learning). This is a learning that "enables anyone to learn at anyplace at any time" (Yahya, Ahmad & Jalil 2010: 117). Ubiquity in future education will develop in several aspects. First, ubiquitous learning will span not only over space and time, but through any media. Thus digitality will allow the students to convert their virtual artefacts into tangible artefacts.

Ubiquity

There is a trend of promoting ubiquitous learning (u-learning). This is a learning that "enables anyone to learn at anyplace at any time" (Yahya, Ahmad & Jalil 2010: 117). Ubiquity in future education will develop in several aspects. First, ubiquitous learning will span not only over space and time, but through any media. Learning will happen in parallel through a variety of media including the social media. Thus
students will have their own imprint on the learning process. Second, teaching will also become ubiquitous. The relation between u-teaching and u-learning is as the relation between deconstructionism and constructionism. The main goal of u-teaching is the decomposition of learning content that renders it u-learnable – this is a challenge with yet unknown complexity.

50 A possible impact of ubiquity on the Virtual Classroom and Mecho is to allow students to play with the software at anytime and anywhere. There are already plans for newer versions of the software based on mobile 3D graphics. This will make the Virtual Classroom and Mecho mobile-friendly and platform-independent.

Transparency
51 Modern technology is getting more transparent and less obtrusive. Much technological and educational power is encapsulated in small yet smart devices. The advance in technology is shifting learning to a new course. I expect that future learners will not learn mathematics, but will experience it. The current model of education creates an image of the world through which people learn. In a technologically transparent future education, people will learn directly from the world around them using all their senses. First attempts in this direction have already been made by the research on virtual, augmented and immersive realities.

52 It is hard to imagine what the virtual classroom would look like in a future of immersive technologies. Most likely, the virtual and the actual classroom will be indistinguishable, or even the same. Because of digitality, ubiquity and transparency, the concept of classroom may become void.

Conclusion
53 Constructionism approaches are applied to education with variable degrees of success. This article describes the application of constructionism to university and secondary school levels. One of the cases is a new course, where students construct virtual mechanisms exhibiting or representing mathematical properties. The other case is of interactive software for inquiry-based learning. This software allows students to conduct experiments in a simulated micro-world, to collect data for raising or proving hypotheses and to investigate unknown relation between entities. Although both cases provide an interesting and motivating medium fostering education in a constructionistic way, there is one specific phenomenon that emerges from every pilot case. It is the phase of deconstruction, which is routinely neglected. A possible reason is the inherent difficulty of the deconstruction. This makes it as hard to achieve as it is to teach creativity.

54 Deconstruction is an important aspect of science and education. Yet, there are no methodological, pedagogical and technological tools that support constructive deconstruction. Education has been incremental for centuries. It cannot cope with the exponential growth of technology and is falling behind. There are efforts to shape the education of the future, including utilizing constructivist and constructionist approaches. However, I advocate that to be able to construct a completely new and adequate education, two steps are needed upfront: (1) acknowledging and supporting deconstruction in education; and (2) the deconstruction of education itself. When these two steps are completed, it will be possible to construct a new type of education. Meanwhile special attention must be paid to three factors: the symbiosis of the two digital educations, ubiquity of learning and teaching and the increasing transparency of technology.

Acknowledgements
The work described in this article is financially supported by: project DFNI-O01/12 Contemporary Programming Languages, Environments and Technologies and their Application in Development of Software Specialists, supported by the Bulgarian Science Fund; project FP7 318499 weSPOT, supported by the EC ICT FP7; project 108/19.04.2013 The Role of IT in the Application of IBL in Science Education and project BG051PO001-3.3.06-0052 Forming a New Generation of Researchers by Supporting PhD, Post-PhD and Young Scientists, supported by the Sofia University Science Fund.

Received: 20 February 2015
Accepted: 21 April 2015

http://www.univie.ac.at/constructivism/journal/10/3/355.boytchev
Open Peer Commentaries
on Pavel Boytchev’s “Constructionism and Deconstructionism”

Deconstruction in Software Construction
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> Upshot - Boytchev's deconstruction-ism looks at first glance like a game of words. Upon a deeper view of the subject, he focuses our attention on the importance of deconstruction to the construction process, which is highly connected to creativity. In my contribution, I want to point out the close relationship of Boytchev's deconstruction to the software development process, where requirements analysis corresponds to deconstruction and software design and implementation correspond to construction. Creativity is an important asset in any kind of software development, where life-long learning is essential.

1. At first glance, the article's title was provocative to me. I felt that deconstruction, as the opposite of construction, means something like destruction. How can destruction help to construct knowledge? I was aware that destruction is the contrary of construction and that destruction is sometimes a necessary prerequisite of construction. Shiva, one of the major deities of Hinduism, is known not only as destroyer but also as creator. Often the need for a construction arises from a destruction. So a close relationship between construction and destruction exists.

2. Pavel Boytchev gives a wise definition of deconstruction: a decomposition of something into reusable entities (§24). These reusable entities can be used in the following construction phase. So deconstruction is not the opposite of construction, it is an essential part of it and incorporates a great deal of necessary creativity. Boytchev's definition of deconstruction is therefore completely different to what can be expected from the title.

3. And why create a new –ism out of deconstruction (§42)? Here, I think it is not justified to define deconstructionism and use it in the same line as constructionism. It is, from my point of view, really a game of words. Deconstruction is, by definition, part of the construction process and therefore subordinate to construction.

4. Boytchev's description of the phases of learning through deconstruction and construction strongly reminds me of core activities of software development processes: requirements analysis, software design and software construction. For more details on software development processes, see, for example, the recent book by Murali Chemuturi (2012). When a larger piece of software has to be developed, first of all the problem domain has to be understood by the developers. The result of analysing the requirements is a structured model of the problem domain. This is usually a decomposition of the problem domain into smaller entities that interact with each other. The main purpose of breaking it up into its component parts is not only the better understanding of the problem domain but also the reuse of the parts in the constructive activities of software design and software construction. In the software design activity, a plan for the construction of the software is created. A part of this plan results from the components of the requirement analysis.

5. Creativity is an essential property of software development. For each problem, there are endless potential software solutions that tackle the problem. It is a creative act to find a better solution that is highly appreciated by users. Not all steps of the software development process can be performed just by following well-defined rules. The experience and creativity of the software engineer strongly influences the outcome of his activities. The way we look at the problem domain and how we deconstruct it into manageable parts strongly influences the quality of the final software product.

6. Why do I connect constructionist learning with software engineering? It is not only the similarity of the processes. It is also the fact that there is constructionist learning in the software industry. It is a life-long learning process that forms good software engineers. They learn from their own and other's drawbacks and successes. So the software engineering activities can be seen as a life-long constructionist learning process.

7. It is not only the future of learning that is massively influenced by the exponential growth in technology (§46), constructionism may also positively influence information technology with its potential in the life-long learning process of software engineers.

8. The two practical examples of constructionist learning that are presented at the beginning of Boytchev's article show very impressively how technology may stimulate the learner's creativity. These technologies are very powerful; they allow a large variety of learning paths and so make room for creativity. The library Mecho (§6) is a very flexible programmable tool that allows
Construction and Deconstruction

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> Upshot • Pavel Boytchev’s article calls attention to the fruitful dialectic between building things and taking them apart: No successful construction without deconstruction. Of course by using the word “deconstruction,” he is also implicitly invoking the critical-theory sense of the term, inviting us to deconstruct constructionism. I found the article fascinating on both levels.

1. This is a very provocative target article. Its central thesis, that deconstruction is essential to successful construction, is an idea that, once stated, is obvious, but it is far out of the mainstream of constructionist vocabulary. I think, though, that the practice of deconstruction may be more prevalent than its analysis.

2. For one thing, it is a commonplace observation that you learn how to build things by looking at, and looking inside, already-built examples. Sometimes this involves physical deconstruction, as in Pavel Boytchev’s example of the child deliberately breaking a toy to see how it works. But I am thinking also of the “Look inside” button on Scratch project pages. The visitor’s first view of someone else’s Scratch project focuses on its behavior and purpose. But by clicking “Look inside,” the visitor can examine the Scratch program that makes the project function, and can even modify or “remix” it.

3. Secondly, people try to build learning environments based on a small number of simple parts. The canonical example is Lego, which has been much more successful than the Erector sets of my own childhood – in which the main components were metal bars of many different lengths that could be bolted together, along with specialized connectors such as angle brackets – in part because of the wide range of projects that can be built out of (many copies of) a single part, the Lego brick. Such environments come pre-deconstructed. The same could be said of the effort in the design of Scratch to minimize block shapes and to minimize the number of primitive blocks altogether.

4. Thirdly, the emphasis on physical stuff in the Maker Movement makes the component parts much more readily visible than in either computer software or even more abstract mathematics.

5. I would be interested in a discussion of how the idea of deconstruction fits in with the (I think) overlapping idea of demystification. One way to demystify a black box is to see how it is built. But there are also demystification strategies that, for example, try to shed light on people’s motivation, or on sociological ideas such as “institution.” Is the purpose of deconstruction demystification, or something else?

6. I think some of the points in the article are made in too much of a hurry. Here are two examples.

7. Debugging as deconstruction ($32): I understand the overall point, I think; in order to debug you have to think analytically about the pieces of a program. And I get that current debugging technology is weak. But I do not think I quite got how a deconstructionist perspective can lead to better debugging tools. This could be a research project in itself, and the one paragraph here leaves me dissatisfied.

8. Technology and education ($45): There is a claim here that very rapid change in technology makes it hard for education to keep up. I see how that would apply for education about technology – which is sort of the point of the Noam Chomsky quotation in §45. And I can see how education might not be making the best possible use of technology: although, for example, schools have been quick to jump on the tablet bandwagon, as far as I know they have not yet found any purpose for which tablets are better than laptops. (I do get that they are cheaper, although now you can get netbooks instead.) But children are not so different in how they construct knowledge, are they? If that is the intended claim, it needs much more discussion. Otherwise the point about exponential change is a little glib.

9. In contrast, the discussion of the virtual classroom project is detailed, vivid, and very convincing. Figures 9 and 10 are a wonderful encapsulation of the central point. I would have been glad if the last few pages of the article were more a laying out of a specific program for future research, rather than a collection of brief mentions of largely unsupported ideas.

10. I do wonder why students of the virtual classroom were required to deconstruct not only the physical model being simulated but also the simulator as a piece of software. Why, for example, make a point of not documenting which keystroke does what in the user interface? Does that deconstruction task not just distract from the deconstruction of the classroom environment?

11. There is another paper to be written about the deconstruction of education. Does that mean something more than the critique of education that starts (maybe) with Jean Jacques Rousseau and goes through John Dewey to Paulo Freire and Ivan Illich? Is there some way in which computers change this critique? What are the component parts of education? Learner, teacher, and content? Maybe plus the learning community? Or does Boytchev mean something more detailed than that? When I visit a school, I generally find myself thinking first not about technology, but
about the social relations in the classroom – mostly the one between the teacher and the students, but also relations among the students.

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Received: 29 May 2015
Accepted: 22 June 2015

“Deconstructionism” –
A Neglected Stage in the Constructivist Learning Process?
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> Upshot - Boytchev identifies “deconstruction” as a neglected but essential stage in the constructivist learning process. Drawing on two studies, one in a university and one in a secondary school, for which software was designed to facilitate constructivist student learning, the author argues that the first phase of learning is the decomposition of knowledge into smaller yet meaningful and reusable entities, which are used as building blocks to construct both personal and new knowledge.

1 Pavel Boytchev’s target article, “Constructionism and Deconstructionism,” encompasses two studies from which is inferred a novel theoretical perspective. Both elements have their merits. While the studies highlight benefits and difficulties of implementing constructivist learning environments, the exposition of “deconstructionism” highlights a neglected stage in the constructivist learning process. On the other hand, the article makes no reference to two highly pertinent sets of ideas, to either a design-based approach that may have informed both the educational technologies and the research studies or to the earliest theory of deconstructionism, by the French philosopher Jacques Derrida.

2 Boytchev’s first study (§§4–11) focuses on the use by university students of a tool, known as Mecho, designed to facilitate the construction of virtual mechanisms by combining basic mechanical components to build simple devices that in turn can be assembled to make complex machines. However, while the software is exciting and appears to have huge potential, the discussion is somewhat superficial. Nevertheless, an especially interesting point emerges.

3 The researchers encountered enormous difficulty encouraging students to use the system to build devices, only around 7% of the students did so in the first year, which the author ascribes to four key “barriers”: insufficient time to learn the new programming language, which was addressed by rewriting the code in a language already familiar to the students; the software interface predominating over its function, addressed by automating much of the interface and its tools; the complexity of Euler-based 3D mathematics, addressed by prioritising ease-of-use over mathematical fidelity; and complex learning criteria, addressed by introducing a predefined structure of learning criteria clusters.

4 The author reports that these “solutions” led to an 8-fold increase in the number of projects completed, but provides no evidence to support such a conclusion. While it does seem likely that making the tool fundamentally easier to use did help those students who chose to explore the software, many other factors may also have had an impact on whether or not they did: factors such as how the software was presented by the instructor, how projects contributed to course credits, and issues of student task comprehension (what exactly are the students supposed to do?) associated with many constructivist learning environments.

5 Boytchev’s second study (§§12–22) focused on an inquiry-based learning project in a secondary school using the Virtual Classroom software designed to help investigate classroom energy use in order to generate ideas for reducing energy wastage. Curiously, the software was “distributed without any documentation,” which meant that the students had to find by themselves all the navigation and experimentation features. However, while the author claims that “the software provoked inquiry learning and active constructionism,” again we are provided with little evidence. Indeed, it is unclear how the students engaged with the software, what they were attempting to achieve or how they went about doing so. This is especially pertinent when claims are being made about constructivist (or constructionist) learning environments, which are known to be unsuccessful if the learner fails to come into contact with the relevant information or if, having done so, fails to make the necessary connections (Kirschner, Sweller & Clark 2006). The issue is that without some guidance, constructivist learning environments “may fail to promote the first cognitive process, namely, selecting relevant incoming information” (Mayer 2004: 17). Even Jerome Bruner (1961) counselled that discovery cannot be made a priori or without at least some guiding theory or knowledge of the domain.

6 The development and research of the Virtual Classroom may also have benefited from the adoption of the iterative and theory-generating approach of design-based research (Design-Based Research Collective 2003). Rather than designing a complete tool and then simply refining it when its limitations become clear, more might have been achieved from an on-going iterative approach, with an initial prototype grounded in theory that is researched in an authentic context, the outcomes of which are used to generate both a second iteration of the tool and local theory – all of which together constitute a process of design, intervention, analysis and reflection that is repeated until robust conclusions may be drawn.

7 Before addressing Boytchev’s “deconstructionism,” some reference has to be made to Derrida’s “deconstructionism,” a critical approach to understanding cultural artefacts that was introduced in the 1960s and predominant in a various diluted forms in much academic discourse in the 1970s and 1980s: “deconstruction is not an opera-
Does Understanding Deconstruction Require Its Deconstruction?  Pavel Boytchev

Author’s Response: Does Understanding Deconstruction Require Its Deconstruction?  Pavel Boytchev

I describe my perception of deconstruction, including the controversial point of view that deconstruction is actually construction. I also provide more details about the some of the design decisions in the software, and how these affected the students’ experience.

My target article was deliberately iconoclastic, and this was also expressed by Gerald Futschek (§1) and Brian Harvey (§1). The article is not to be considered as a final research piece. Instead, it is more like a wake-up call, trying to throw readers off-balance. I did not give answers, I only raised questions.

In the summer of 2013, I reached the idea of deconstruction as a process that is essentially part of construction. This was publicly announced at Constructionism 2014 in Vienna. A long time before that, I had a vague idea about something mysterious that happens during learning. It became less vague to me when I named it “deconstruction.” The reason for picking exactly this name was to capture the essential idea and importance of this process. I found that “deconstruction” was already loaded with some meaning. As Wayne Holmes (§1, §7) mentions, Jacques Derrida introduced “deconstruction” some 50 years ago. Yet, his deconstruction does not map sufficiently with my idea. To minimize misunderstanding, I gave a specific definition of what I mean by “deconstruction” in §24 and again in §38; and peer comment authors have acknowledged this definition (Futschek §2; Holmes §8).

The constructive nature of deconstruction

In §26 and §31, I discussed briefly the creative nature of deconstruction. Why did I think it so? If construction is creative, why should deconstruction be creative too? Changing the perspective, one can see that deconstruction is a process of construction of small entities. This construction is non-deterministic (§42) and creative.

This raises the question of whether it is possible to support deconstruction. Harvey (§§21) drew parallels with Lego bricks, an Erector set and Scratch, while Holmes (§8) described “previously deconstructed elements of knowledge,” prepared and deconstructed for the students. Indeed, these parallels visualize nicely that the direct result of deconstruction is a set of simple entities used to (re)create knowledge. It may appear that such pre-deconstructed sets would ease (de)construction, and this might be correct. However, I see a disadvantage. The process of decomposing into basic “bricks” is an essential process: what Lego, Erector, Scratch, Logo or any previously deconstructed element does is to bypass this process, effectively nullifying its eventual educational impact. I consider deconstruction to be a creative process, and different people may want to deconstruct the same thing into different sets of elements.

Here is a personal example. In my early years I studied how to add numbers. There was an algorithm for how to do this, simple and effective, but I used my own...
algorithm. For example, I would calculate \( 85 + 37 \) by transferring quantities from 37 to 85 in a way that zeroes its least significant digits one by one:

\[
85 + 37 = (85 + 5) + (37 - 5) = 90 + 32 = (90 + 10) + (32 - 10) = 100 + 22 = 122
\]

I could do the opposite too:

\[
85 + 37 = (85 - 3) + (37 + 3) = 82 + 40 = (82 - 60) + (40 + 60) = 22 + 100 = 122
\]

Forty years later, I still use this approach, not the one in the textbook.

« 6 » In §5, Harvey raises an interesting question about demystification. According to me, the relation between deconstruction and demystification is that demystification is just an interim subprocess during deconstruction. Demystification does not encompass the idea of subsequent (re)creation and its goal is not to create reusable entities.

« 7 » I understand that the topic of deconstruction and deconstructionism needs far more attention and detail. It was impossible to discuss all the issues in sufficient depth in a single article. So I agree with the observations of Holmes (§2, §9) and Harvey (§§6f). I also agree with the suggestion that “there is another paper to be written about the deconstruction of education” (Harvey, §11).

The software environments

« 8 » I based our discussion about deconstructionism on the software environments developed for and used by research projects. These projects had their own goals, plans and results. I mention this just to make it clear that the purpose of Mecho and Virtual Classroom was not to investigate deconstructionism. However, I found these environments deconstructionism-friendly.

« 9 » The idea of adopting the design-based approach, suggested by Holmes (§6), is interesting. It might have been used in the development of Virtual Classroom if it had been developed as a standalone project. In fact, the development of the environment was governed by specific requirements of the weSPOT project. Additionally, the Virtual Classroom software was not the primary software developed in weSPOT, it was just an add-on facilitating some pilot experiments.

« 10 » Similarly, while I used Mecho, I collected data relevant only to the goals of the corresponding research project. Holmes (§4) is right that many factors may have contributed to the success of Mecho. The instructor in all classes was the same person and he was also the author of all versions of Mecho. So, more or less, the presentation style in all courses was practically the same. Further courses will provide more data and then it will be possible to refine the exact contribution of each factor.

Students’ reactions

« 11 » The experience of the students with the software environments was discussed in other papers as part of the dissemination activities of the corresponding projects. Three of these papers are included in the target article (Boytchev et al. 2014; Stefanov Nikolova & Stefanova 2013; Stefanov et al. 2013). Harvey (§11) expressed the importance of social relations in the classroom. The three papers contain further details about what actually happened in the classroom and how students communicated, and I also published some of their conversations.

« 12 » The decision to challenge the students (and their teachers) with the software environment Virtual Classroom without providing any documentation was described as risky in §20. Both Harvey (§10) and Holmes (§5) confirmed it was indeed risky and shared their doubts about its advantages. Of course, I do not claim that such approach will work in every case; I just saw an opportunity in a situation where the lack of documentation might be advantageous. And I utilized this opportunity.

« 13 » In a nutshell, the students experienced no problems with the lack of documentation, they had no problems navigating and managing the virtual microworld. Nowadays, when students try new software or hardware, they spend no time studying its documentation. They just start playing with it right away, using their experiences with other technological tools. When they face problems, they first ask their friends. If the problems are still unresolved, they check the documentation. This answers Holmes’ (§5) concerns that constructivist environments require guidance or knowledge. The software was designed in such a way as to match the students’ experience with other software (such as games).

Deconstructionism and technology

« 14 » As I talk about technology and how students experience it, I reach another important idea of our article – a change of technology changes how people interact, communicate and explore new things. As a result, it also changes how people (prefer to) learn. Harvey (§8) found it unconvincing that new digital devices, such as tablets, might have significant positive impact on education. In my article I was not concerned with the discrepancy between the current state of technology and the current state of education. I was concerned with the discrepancy between the current speed of change of technology and the current speed of change of education. In this respect, tablets, digital watches and smart glasses are mere artefacts of today’s technology. Tomorrow they will be replaced by something else.

« 15 » Technological development is exponential, as noted in the target article (§46) and by Futschek (§7). On the other hand, education is still conservative. It changes, but incrementally. As a result, the gap between technology and education is predestined to become larger unless education makes a significant leap forward. In the past, it was education that empowered people’s life, today it is technology (this is a harsh claim, but see the end of §1 of this response).

« 16 » At the end of his comment, Harvey (§11) asked a series of interesting questions that may push the idea of deconstruction further. Additionally, as Holmes (§7) suggested, I shall revisit Derrida’s work to look for a stronger relation between his deconstruction and our deconstruction. Although both deconstruction domains are quite different, the conceptual foundation might be quite similar. I am particularly happy with how Futschek (§§4–6) described software development from a deconstruction-construction point of view. I believe that once deconstruction has a name, it will be easier to demystify it and then to use it. Again, being provocative, I see this demystification as recursive activity – to understand deconstruction, one has to deconstruct it.
Combined References


Learning about Learning with Teachers and (from) Young Children

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> Context • Convictions arising from different, separate and distinct domains and paradigms (modeling-based learning (MbL), Papert’s constructionism, literature on play from the domain of early childhood education, complexity theory) agree in favor of a need for a shift in education that will allow (young) children to access what Papert refers to as “hard learning” that consequently leads to “hard fun.” > Problem • Nevertheless, such an achievement demands supporting learning in a manner that seems difficult for teachers to comprehend and handle. > Method • In this article, we provide three learning stories. These constitute parts of an effort to develop a joint mathematics and science curriculum for early childhood education parallel to supporting teachers so that they deliver and, at the same time, are able to value and assess the learning involved. The first story concerns teachers’ learning whereas the second and third story concern 5-year-olds’ learning. > Results • In all three stories, we see how the researcher (author), teachers and children learn (about creative learning) together. By the end of this article, the three stories will allow us to describe and redefine MbL and at the same time highlight the constructionist foundations of Mbl and the common ground between MbL and the constructionism paradigm. > Implications • Furthermore, the stories as a whole will allow us to argue that all it takes to move away from traditional practices is a shift in how learning is conceptualized. > Constructivist content • The article is built on the constructionism approach, which focuses on the value of learners acquiring access to powerful ideas through meaningful constructivist learning processes. > Key words • Mathematics, teacher education, modeling-based learning, early childhood education, creative learning.

Introduction

1 Mathematical models are used to construct, interpret and mathematize real-world problems, or structures, phenomena and situations (English, Fox & Watters 2005; Lesh et al. 2013). Research has documented that children are capable of more complex thinking and reasoning (Fox 2006) and...

2 can learn to model, generalize, and justify at earlier ages than traditionally believed possible, and that engaging in these practices provides students with early access to scientific and mathematical reasoning. (English & Watters 2005: 60)

Research has gone beyond traditional hierarchies and has provided proof that the access to “big ideas” need not be “postponed until after students have been taught calculus” (Lesh et al. 2013: 420). However, despite the justification for the inclusion of modeling in education, and the need to make powerful ideas accessible to children at an early stage, modeling-based learning (MbL) is not commonly incorporated into educational practice or early childhood education.

3 Literature is rich with (research) examples of children doing wonderful things. So why is this not reflected in schools and in teachers’ everyday practice? Brent Davis and Dennis Sumara (2000: 830), in describing complexity as a theory of education, describe their experiences as teachers in the 1980s and of completing yearly plans based on “orderly, sequential, grid-like structures.” They acknowledge that this kind of planning is “easy to make,” “commonsensical, familiar, reassuring.” Furthermore, linear planning leads to well-defined and recognizable knowledge-based objectives that reflect what, as stated by Seymour Papert (1998: 88), is worst about school curriculum: the fragmentation of knowledge into little pieces that, “is supposed to make learning easy; but often ends up depriving knowledge of personal meaning.” Moreover, as suggested by Davis and Sumara,

4 such imperatives as the pre-specification of learning outcomes and the articulation of comprehensive lesson plans, […] can eclipse the richness embodied in any moment of engagement with a subject matter […] and […] are incongruent with the diversity and complex texture of activity present in any learning story.” (Davis & Sumara 2000: 830)

5 Learning, from Jean Piaget’s constructionism and Papert’s constructionism perspective, is always highly connected with play. As stated by Mitchel Resnick (2014: 18), within a constructionism perspective, play is conceived “as an attitude and an approach for engaging with the world.” Play is associated with “taking risks, trying new things, and testing boundaries, […] a process of tinkering, experimenting and exploring.” And as Resnick concludes, “these aspects of play are central to the creative learning process” (ibid: 18). But defining learning activities that have the characteristics of play can be problematic for teachers. As Lesley Abbott states,
defining play within an educational context can, for some teachers, be problematic since many of the characteristics we associate with play – freedom, spontaneity, exuberance, fun, ownership – do not sit happily or naturally within a context geared to prescriptive programmers, long-term planning or summative testing. (Abbott 1994: 77)

« 4 » In the previous three paragraphs, we have referred to convictions arising from different and distinct domains and paradigms (MbL, constructionism, literature on play from the domain of early childhood education, complexity theory). Nevertheless it is apparent that there is a consensus that there is a need for a shift in education that will allow (young) children access to what Papert (1998) refers to as “hard learning” that consequently leads to “hard fun,” which, though, demands supporting learning in a manner that seems difficult for teachers to comprehend and handle.

« 5 » Thus in this article we provide three learning stories that constitute parts of an effort to develop a joint mathematics and science curriculum for early childhood education. The aim of this effort was not only to provide a learning model to empower learning that has a complex and rich texture but at the same time to support teacher’s learning and at the same time to support the characteristics we associate with play – freedom, spontaneity, exuberance, fun, ownership – as mathematicians (Papert 1972), at “doing mathematics” (Nunes & Bryant 1996) rather than being taught mathematics. Learning was therefore seen as a process, resembling that used by mathematicians in scientific communities, of posing questions and problems, formulating hypotheses, designing, collecting and analyzing data, experiences and observations, formulating conclusions and constructing or reconstructing theories. Thus emphasis was placed on processes for supporting learners to construct meanings of the world that surrounds them.

« 6 » The PLEGMa project was built on constructionist approaches to mathematics education that emphasize inquiry-based learning. Such approaches do not simply aim at mathematics knowledge acquisition, but also at understanding the processes by which mathematicians study the mathematical world, at teaching children how to think as mathematicians (Papert 1972), at “doing mathematics” (Nunes & Bryant 1996) rather than being taught mathematics. Learning experiences of the teachers involved in the PLEGMa project is reported in Philippou, Papademetri-Kachrimani & Louca (2015). This article, however, reports selected key stories from the PLEGMa project in an effort to describe and redefine MbL not only as a process supporting children’s learning but also as a process for supporting teacher’s learning and at the same time highlighting the constructivism foundations of MbL and the common ground between MbL and the constructionism paradigm.

The context of the stories: Activities and sources of data

« 7 » The PLEGMa project aimed at supporting teachers through their participation in professional development programs to experience such learning in mathematics for themselves and reflect upon this way of learning and their existing teaching practices (the first part of the program, comprising five three-hour meetings over two and a half months) and, finally, to proceed with designing and implementing activities for young children following a cyclical process of data collection and analysis and reflection (the second part of the program, comprising seven three-hour meetings over four and a half months). Thus teachers first experienced what they were later expected to enact with children.

« 8 » A reflective study exploring the experiences of the teachers involved in the PLEGMa project is reported in Philippou, Papademetri-Kachrimani & Louca (2015). This article, however, reports selected key stories from the PLEGMa project in an effort to describe and redefine MbL not only as a process supporting children’s learning but also as a process for supporting teacher’s learning and at the same time highlighting the constructivism foundations of MbL and the common ground between MbL and the constructionism paradigm.

http://www.univie.ac.at/constructivism/journal/10/3/370.papademetri
Act 1: How many circles are in the shape?
The teachers are asked to find as many different ways as they can to count the circles in the shape.

Act 2: How many circles will there be if we make the shape bigger?
The teachers are introduced to the sequence created by making the shape (Figure 1a) bigger and smaller. They are given the first four shapes of the sequence (Figure 1b) and are asked to formulate a hypothesis to predict how many circles the 5th shape in the sequence will contain.

Act 3: Programming a robot to make the shapes using circles.
The teachers are introduced to the idea of an imaginary robot that can follow simple rules to construct shapes using bottle lids. They are asked to formulate a set of very simple directions, which when executed by the robot, will result in the construction of any of the shapes shown in the sequence. It is made clear that the robot (a) can only understand and follow very simple words and directions, (b) cannot count more than two objects and (c) does not understand any formal mathematical language.

Figure 2 • Overview of the AS of Story One.

Figure 3 • Overview of the AS of Story Two.

square numbers, which was designed (along with other ASs) by the mixed group of researchers and teachers during the second part of the professional development programs that were implemented as part of the PLEGMA project. The teachers involved in the activity-designing process originally participated in the AS presented in the first story and had the opportunity to reflect upon the context of learning, their own practice and this new way of doing mathematics. Parallel to the design process, the AS presented in the third story was gradually implemented by one of the teachers in her class. The data she collected each week was analyzed by the group and gradually reinforced the development of both the AS and the joint mathematics and science curriculum.

Story One: Teachers’ learning through modeling

The data sources for all three stories included video-recordings of the implementation of the activities, the instructor’s/teacher’s reflective field notes (the author’s article in Stories One and Two; the teacher that implemented the activity in Story Three) and the artifacts/representations produced by the teachers (Story One) and the children (Stories Two and Three). In the following narratives and analysis, key events from the stories are selected that will allow us to address the aims of the article. Thus common aspects within the three stories are pinpointed in order to describe and redefine MbL as a process for supporting teachers’ and children’s learning and at the same time highlight the constructivism foundations of MbL and the common ground between MbL and the constructionism paradigm.
Figure 4 • Selected solutions from Act1 (Figure 2).
The need for the equation arises mostly from a need for a representation to provide a specific number as an answer to the original question (How many circles are there in the shape?).

"15" One important remark concerns the way in which the two types of representation (graphical and equation) can complement each other. Take for example the following sets of solutions (Figure 4): (S2, S10) (S13, S32) and (S4, S18), which correspond to the following equations:

\[ 4 \times 5 + 20 \]

\[ 16 + 12 + 8 + 4 + 1 = 41 \]  \( H_1 \)

\[ (5 \times 5) + (4 \times 4) = 41 \]  \( H_2 \)

\[ 1 + 3 + 5 + 7 + 9 + 7 + 5 + 3 + 1 = 41 \]  \( H_3 \)

\[ 4 \times 5 = 20 \]

\[ 5 \times 1 = \frac{20}{5} \]

\[ 4 \times 4 + (3 + 4) \times 4 + 1 = 41 \]  \( H_4 \)

\[ (4 \times 6) + (4 \times 1) + (7 \times 2) - 1 = 41 \]  \( H_5 \)

\[ (1 \times 9) + (2 \times 7) + (2 \times 5) + (2 \times 3) + (2 \times 1) = 41 \]  \( H_6 \)

Even though the equation of each solution in each set is the same, the manner in which the problem was approached was different, and this is apparent from the graphical representation, which constitutes a vital source of information regarding the thinking and observation involved.

"16" On the other hand, the graphical representation is not enough to comprehend fully a certain solution. Take for example S7 and S8 (Figure 4), which graphically are very similar. Yet the equations give more information about the actual thinking. Whereas the teacher who devised S7 saw two lines (and probably counted the circles of one line and multiplied that by 2) in the center of the shape, the teacher who came up with S8 saw a cross (and probably counted all the circles in the cross one-by-one).

"17" Similarly, in the case of S3 and S4 (Figure 4), where both teachers saw lines of circles, the corresponding equation is different:

\[ 1 + 3 + 5 + 7 + 5 + 3 + 1 + 25 \]  \( S3 \)

\[ 1 \times 2 + 2 \times 3 + 2 \times 5 + 7 = 25 \]  \( S4 \)

In S4, the lines are grouped and this is expressed in the graphical representation through the use of the same color and translated in the equation through the use of multiplication. Finally, let us look at S2 and S29, constructed by the same teacher. In S2 the shape is perceived as consisting of lines of 4 and 3 circles forming a pattern, whereas in S29 the shape is perceived as consisting of two squares, a 4 × 4 and a 3 × 3 square.

"18" The aim of the activity at some point (in some cases spontaneously and in some cases with encouragement from the instructor) focuses on “How can you count the circles in the shape using the least possible counting?” As a result, we have (a) strategies of grouping parts of the shape into lines and shapes consisting of equal numbers of circles (Figure 4, S21–28) (b) strategies of discovering rectangles within the shape, which allows a quick way of counting using multiplication (S10–12, Figure 4), and (c) ‘clever,’ creative solutions (Figure 4, S29–32). When the teacher who suggested S32 was asked how he had thought up this solution, he answered, “I thought that since the answer to the problem is 25, we can probably find a solution by creating a 5 × 5 square. So I thought about moving around some of the circles to transform the shape into a 5 × 5 square.” This shows a shift in the teacher’s effort from counting the circles to being creative.

"19" In Figure 5, we have an overview of the different hypotheses (H) formulated by teachers regarding Act2 (Figure 2). In order to formulate a hypothesis, the teachers have in front of them the four first shapes of the sequence (Figure 1b). By observing the sequence, they usually notice that each shape is a repetition of the previous shape, with the addition of a square of circles around the outermost edge of the existing square. Counting the number of circles added each time leads them to a sequence consisting of multiples of 4 (4, 8, 12) and thus they hypothesize that the 5th shape in the sequence will have 16 circles more than the 4th. When the teachers explain this hypothesis, the instructor asks them to return to the solutions from Act1 and identify the solution that connects to this hypothesis (Figure 5, H1). When this is achieved, the instructor then asks them to find other solutions that might lead them to formulate
alternative hypotheses that lead to the same result as before. As a result, the teachers formulate other hypotheses like the ones described in Figure 5.

« 20 » The numerous cycles of implementations conducted over the years have allowed teachers’ possible behaviors during their involvement in Act3 (Figure 2) to be recorded and an instructor’s protocol has been drawn up based on these. Both behaviors and protocol are based on the set of rules described in Figure 6, which has been gradually constructed and refined over time. In Papademetri-Kachrimani (2014), there is a more thorough description of these possible behaviors and the suggested instructor’s protocol. In this article, I would like to focus on a specific behavior that arises in almost all groups of teachers, and concerns rule 2 (Figure 6). After the teachers struggle to write their rules in groups for quite a while, they normally end up with a set of rules similar to those described in Figure 6 but omitting rule 2. The resulting set of rules does not take into account the fact that the shape is constructed of horizontal lines, each comprising of an odd number of circles. At this point, the instructor takes the role of the robot and when instructed to take lids (rule 1) inten-
tionally picks up an even number of lids. The instructor follows all of the rules by making horizontal lines. At some point, the rules lead to a horizontal line consisting of two circles. Thus on reaching rule 5, a problematic situation arises, since by removing the first and last lid, the line is left with zero lids. This comes as a surprise to the teachers since up to that point they think that they have come up with the “correct” set of rules. This moment of surprise is always magical. After overcoming their surprise, they “turn” and take a better look at the shape of circles and compare it with the shape constructed by the instructor following their instructions. This process leads them to the realization that all horizontal lines in the shape consist of odd numbers of circles; the need to formulate a set of rules that correspond to the concept of odd numbers arises, and gradually they reach a version of rule 2 (Figure 6).

**Story Two: Children learning through modeling**

« 21 » In Figure 7, we see selected solutions (S) from the children’s involvement in Act1 (Figure 3). It is important to stress the commonality between the Ss in Figure 7 and the adults’ Ss presented earlier (Figure 4). Even though the aim of the activities was different (the adults’ aim was to find different ways to count the circles, whereas the children’s aim was to find different ways to use two colors in the shape), the result is very similar; and through the process, an in depth collection of data, observations and experiences in relation to the shape was achieved.

« 22 » As in the case of the adults, the children saw different shapes and lines in the shape that they represented with two different colors. We will not comment more on the Ss, which were common with the adults’ Ss. However, we would like to stress the uniqueness of S7–9, which do not match any of the adults’ solutions, and the simplicity of S10 (Figure 7). The results from the children's involvement in Act2 (Figure 3) were similar to those presented in Figure 7 since the children based their reconstructions of the shape on their observations and representations from the previous activity. So they tried to remember ways they had used the two colors in the shape in order to reconstruct it and thus count the circles. In Figure 8, we can see the results from some children’s efforts to make the shape bigger or smaller (Act3, Figure 3). Once more, the children’s efforts are a continuation of the representations they came up with in Act1 (Figure 3).

« 23 » By observing the children involved in the AS, we realized that the children’s representations were not enough to describe in detail the mental processes the children underwent. One noteworthy example concerns S3 (Figure 7), which resembles one of the common Ss followed by adults (Figure 4, S2). But by carefully observing the children, or by asking them to explain to us how they came up with this S, we identified that in most cases the children followed a process of trying to apply a pattern of making one circle one color and the next circle another color in each horizontal line and not one diagonal line one color and the next diagonal line another color as in the case for the adults. So, whereas the visual representation of the adults and the children is the same, the manner in which the shape was conceived was different due to the different focus of the activity in each case. Furthermore, in the story that follows we shall see how this exact representation was conceived by the same child in multiple ways.

**Steven’s story**

« 24 » In this part of the article, we would like to introduce 5-year-old Steven (pseudonym). At the beginning of the AS, Steven stated that he could see a lot of small circles creating rhombuses in the shape. Steven was very consistent and based all of his efforts in reconstructing and representing the shape on this observation. The paradox is that even though he was consistent, Steven exhibited an amazing ability to “see” the shape in many different ways.

« 25 » Figure 9 illustrates Steven’s attempt to represent the shape on a felt board in an effort to use two colors (Act1, Fig-
It took Steven 20 minutes to complete the representation, mainly because of practical issues (the circles kept falling off the board and as a result on many occasions he had to start over again). Despite the difficulties, it was his choice to complete the task even though he did feel distressed and discouraged at some points. In Figure 9, we see two of his attempts. After analyzing Steven’s sequence of actions relating to the first attempt, we concluded that Steven was simultaneously viewing the shape in the three different ways represented in the second column of Figure 9. In his second attempt, we see Steven following a different strategy by creating a square of red circles on the outside of the shape, thus conceiving the shape as presented in the corresponding representation in the second column of Figure 9.

After a few days, when Steven attempted to reconstruct the shape in order to address the aim of Act2 (count the circles in the shape), he followed an entirely different strategy. He began his attempt by constructing a triangle like the one highlighted in the first photograph in Figure 10. He constructed this by constructing one red line and one yellow line repeatedly, as presented in the representation in the second column of Figure 10. He then continued with the other side of the shape, as presented in the second photo (Figure 10).

In his effort to make the shape bigger (Act3, Figure 3), Steven continued to be consistent in seeing the shape as a shape with circles that create rhombuses, as he constructed the shape in Figure 11a. But the most astonishing part of the story is what happened when the author decided to ask Steven to try and make the shape (Figure 1a) smaller. Steven did not start his effort by reconstructing the shape from the beginning. He began by observing what he had just constructed (Figure 11a) and reached his hands to make alterations as to address the new challenge. As presented in Figure 11b–d, even though Steven seemed quite confident that he could do it, on numerous occasions I tried to stop him, at some points even grasping his hands (Figure 11c). I was hesitant to allow the child to proceed because if he “messed up” it would be difficult to go back. At that moment I really valued computers and the undo options.

http://www.univie.ac.at/constructivism/journal/10/3/370.papademetri
available. Nevertheless, it turned out that I simply had to show more trust. Seeing Steven’s persistence and confidence, I finally decided to let him proceed. Amazingly, Steven, with a simple circular movement removed the two rhombuses of circles (one red, one yellow) created on the outside of the shape (Figure 11d), thus resulting in the shape presented in Figure 11f.

« 28 » While I was still trying to figure out what he had just done, Steven
- stood back, stretched his hands down and shouted in victory “tata” (Figure 11e),
- then started moving his hands up and down making an “I am done!” gesture (Figure 11f).
- He removed his name tag and placed it next to his construction (Figure 11g),
- started pushing the lids he had removed from the shape further back so that they would get out of the picture (Figure 11h)
- finally started running around the room asking for a camera.

Someone handed him the camera and he gave it to me to take a picture (Figure 11i). Putting their name tag next to something they had created for a photo to be taken was a routine the children were accustomed to. Adults would use this routine to collect data and at the same time use the photographs with the children for reflection as part of the learning process.

« 29 » In order to complete the story, we consider it necessary to provide a synopsis of an example of an AT developed with teachers as part of the PLEGMA research project. Thus in Figures 12–15, we provide some of the results from the implementation of an AT concerning square numbers. Even though the implementation lasted five weeks and the data were rich, here we provide only four key stages from the process, accompanied by selected data collected from the implementation.

« 30 » As described in Figure 12, the teacher introduced the children to an 8 × 8 structure constructed with bottle lids, which the children had the opportunity to observe and describe. Then, the teacher challenged the children to construct similar shapes and provided them with quantities of lids in two different colors (Figure 13). A week later, the children received a letter from a friend asking them to send him instructions on how to make a similar shape using only 12 lids in total. After trying to make the shape with 12 lids and despite their confidence that they would manage to do so, the children, surprised, concluded that it was impossible. They concluded that in order to make the shape you either needed more lids (4) or you could make the shape using only 9 lids (Figure 14). Finally, the children “wrote” letters to send to the friend explaining to him (a) what they had discovered, and (b) what was necessary in order to construct the shape (Figure 15).

Through this process and following an iterative procedure of data, experiences and observation collection, the children constructed a conceptual understanding of square numbers, which resulted in the representations they used to reply to the friend’s letter.
Conclusion

« 31 » In this article, we value Celia Hoyles’s (2002: 284) persistence in the conviction “that studies in mathematics education should involve some discussion of mathematical activity, however this is defined,” a conviction also shared by Richard Lesh et al. Their results support their opinion that even though what they call model-eliciting activities…

**are designed for research purposes, they also are proving to be remarkably effective learning activities – especially if attention shifts beyond low-level facts and skills towards an emphasis on deeper and higher-order understandings.** (Lesh et al. 2013: 424)

In the case of this article, though, the connection is rather the reverse. The learning activities designed for teachers and children turned out to be very effective for research purposes.

« 32 » In the previous sections of the article, we saw how both teachers (Story One) and children (Stories Two and Three) came to understand better a certain structure through their involvement in a variety of activities. Their efforts to solve problems, which involved a process of collecting observation, data and experiences and representing these in different ways, resulted in a deep understanding of the structure under study. Figure 16 provides an overview of the learning described in the stories “told” in the previous sections of this article.

« 33 » Through the data presented in all cases, we saw how the learner (adult/child) would gradually start collecting experiences, data and observations concerning the relevant structure and then proceed...
with representing those experiences and observations using different means of representation (Figure 16a). The motive for involvement in this process (collecting observations and the act of representation) arose through the problem/challenge given by the instructor/teacher in each case (Figure 16b). But it was apparent from the data that these three phases (facing a problem/challenge, collecting experiences/data/observation and the act of representation) were not three distinct phases of the process. A close look at the data collected underpins the dynamic interplay between the three. Thus in order to address the original question/problem/challenge, learners start observing the shape/structure, and in order to record and communicate their observations, they then proceed with their representations. At the same time, the act of representing allows the participants better to understand the shape (make more observations) and form strategies to find other, different solutions to the original problems. This process (Figure 16b) occurs repeatedly (Figure 16c) through the learner’s participation in the AS, since each activity in the sequence begins with a new problem/challenge that drives towards a new cycle of collecting observations and making representations: a process that leads the learner to construct gradually a deeper understanding of the phenomenon/structure/concept under study.

« 34 » In describing how it feels to be involved in this ASs (and this applies to the instructor/researcher as well as the teachers and the children), I would like to use a quote from Edith Ackermann’s attempt to compare Piaget’s constructivism with Papert’s constructionism:

“...I also share Papert’s view that diving into the unknown, at the cost of experiencing a momentary sense of loss, is a crucial part of learning. Only when a learner actually travels in a world, by adopting different perspectives, or putting on different ‘glasses,’ a dialogue begin between local and initially incompatible experiences.” (Ackermann 2004: 23)

But who is the learner in the stories reported in this article? And is this article about children’s learning or teacher’s learning, and if it concerns both, what is the relationship between the two?

« 35 » Elliott Eisner states that “in the arts and in subject matters where, for example novel or creative responses are desired, [...] the end achieved ought to be something of a surprise to both teacher and pupil” (Eisner 1983: 88). Even though Eisner (1983) states that in some subject areas, such as mathematics, this might not be the case, and in extension of Ackerman’s position, we value that the end of learning achieved in any learning situation concerning any subject matter should have elements of surprise for both the teacher and the pupil. This element was apparent in all stories reported in this article, but we shall return to this shortly. This conviction is also emphasized by Lawrence Stenhouse (1970) through his opposition to the use of objectives in curriculum research and planning, which is a position important for this article since, as described in the introduction, the stories reported arose from a curriculum development process. As stated by Steve Bartlett and Diana Burton, Stenhouse found the ‘objectives model’ of curriculum design to be uneducational as it assumed knowledge as a given and discouraged wider questioning and individual development while encouraging passive acceptance of the facts as presented. [...] For this reason Stenhouse favoured a process model of curriculum design that was based upon learner’s questioning and exploring in order to gain their own understanding. Teachers themselves, while having knowledge about what they are teaching, are cast in the role of learners alongside their students. For Stenhouse it was
This conviction brings us back to the point stressed by Davis and Sumara (2000: 830) concerning the “pre-specification of learning outcomes and the articulation of comprehensive lesson plans, […] that can eclipse the richness embodied in any moment of engagement with a matter subject” and Papert’s (1998) opposition to the fragmentation concerning the “pre-specification of learning”.

Now, what do the stories reported in this article tell us about the common ground between MBL and constructionism? The teachers in Story One were surprised when their set of rules for “programming” the robot did not work, which led them to formulate a set of rules for defining odd numbers. Even though here teacher-adults are involved, there is an apparent connection with the way Papert describes learning in Mindstorms:

“[M]any children are held back in their learning because they have a model of learning in which you have either ‘got it’ or ‘got it wrong.’ But when you learn to program a computer you almost never get it right the first time. […] The question to ask about the program is not whether it is right or wrong, but if it is fixable. If this way of looking at intellectual products were generalized to how the larger culture thinks about knowledge and its acquisition, we might all be less intimidated by our fears of ‘being wrong.’” (Papert 1980b: 23)

Now it seems than only if teachers have the opportunity to experience learning in that way (and reflect upon this way of learning) can they apply it in their classrooms and consequently to children’s learning. As reported by the teachers’ involved in the PLEGMA project themselves, they felt like students learning and that then they had to implement what they had learned (Philippou, Papademetri-Kachrimani & Louca 2015: 388). One teacher specifically stated that from her participation in the program, she felt the need to observe and search and added “I have also put the children in this position, every time we are going to do something new, we will investigate and search” (ibid: 392). So what the teachers learned from their involvement in the learning situation of Story One they then applied in their classrooms and ended up with learning situations like the one described in Story Three.

Even though the activities reported in this study did not involve the use of digital tools, they borrowed approaches in programming that had similar outcomes as the ones reported in related literature. Look back at Story Three and the children’s attempt to describe the conditions necessary for ending up with a square structure, which was indeed a representation of the children’s construction of the concept of square numbers. In the representations demonstrated in Figure 15, the children “explained” that in order to end up with a square structure you need to put the same number horizontally and vertically. This followed the children’s surprising discovery that not all numbers (e.g., number 12) can allow us to construct square structures.

In all learning situations described in this article, the outcome was unknown to the teachers and the learners involved. This applies to the teachers undertaking the role of the learner in Story One and the role of the teacher in Story Three. And this also applies to the author of this article undertaking the role of the teacher in Stories One and Two and the role of the researcher supporting the teacher in Story Three. The surprise element in Story Two concerned my lack of understanding of what I know now after analyzing the data.

This article builds on the conviction that a good way to start educating and supporting teachers to implement MBL, or any other approach that moves away from their traditional practice, is to allow teachers to experience “diving into unknown situations at the cost of experiencing a momentary sense of loss,” and allowing and supporting them to use this experience to reflect upon and refine their practice.

Received: 22 February 2015
Accepted: 25 April 2015
Open Peer Commentaries
on Chrystalla Papademetri-Kachrimani’s “Learning about Learning with Teachers and (from) Young Children”

Backwards-and-Forwards from the Unexpected: Teachers as Constructionist Learners
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> Upshot • The activities that Papademetri-Kachrimani presents in her stories create situations that lead to unexpected results, thus opening the potential for learning about learning in teachers’ professional development. These integrate modeling-based learning (MbL) – arguably a form of constructionism –, and allow learners to move back-and-forth between representations in order to develop strategies and rules.

« 1 » Chrystalla Papademetri-Kachrimani’s target article presents three stories of teachers or children confronting questions related to what can be described as puzzle activities with bottle lids, which lead to surprising results for all involved (teachers, children and even the researchers). The idea of creating situations that lead to unexpected results, which open the potential for learning, is one of the aspects that I enjoyed most about the article. This is nicely referred to in the article through the Ackermann statement that diving into unknown situations – which can take the learner to experience a momentary sense of loss – is a crucial part of learning, leading to the adoption of different perspectives and a dialogue for reconciling incompatible experiences (Ackermann 2004, cited by Papademetri-Kachrimani). Certainly the activity sequences proposed follow a constructionist paradigm in that learners engage in processes of reflection, discovery and construction of strategies; as Papademetri-Kachrimani points out, these activities did not involve the use of digital tools, but the construction of strategies and, more so, the definition of rules (public and shareable rules) is akin to the computer programming that is at the core of the constructionism.

« 2 » A central focus of Papademetri-Kachrimani is on encouraging the integration of modeling-based learning (MbL) activities into teachers’ practices. Let us consider the relationship between the two theoretical perspectives: MbL and constructionism. I myself have always considered that there is a deep connection between MbL and constructionism, and have used it in my own work. For Richard Lesh and Helen Doerr, from the modeling perspective, problem-solving activities are those involving sharable, manipulatable, modifiable, and reusable conceptual tools (e.g., models) for constructing, describing, explaining, manipulating, predicting, or controlling mathematically significant systems.** (Lesh & Doerr 2003: 3)

If we consider that constructionism proposes that learning and the construction of knowledge “happens especially felicitously when the learner is engaged in the construction of something external or at least shareable” (Papert 1990, cited in Cavollo 1999: 134), and promotes presenting students with environments, situations, or objects to “think with” that can help them engage with particular powerful ideas through exploration and discovery (Papert 1980a), then we can clearly see the connections that can lead us to affirm that MbL is a form of constructionism.

« 3 » However, despite decades of successful constructionist examples reported in the research literature, the implementation of constructionism in schools has proved difficult. Likewise, Papademetri-Kachrimani asks why teachers have difficulty implementing MbL in educational practice. She mentions how it is easier for teachers to adhere to pre-defined program plans while central aspects of constructionism such as play, fun and creativity are problematic for teachers and the traditional schooling system. I would add to that the fact that teachers tend to teach the way they have been taught, with their beliefs about teaching and learning shaped by their own experience as students (Ball 1988, Thompson 1992). This is why Papademetri-Kachrimani’s approach to have teachers experience the same type of activities that she promotes students to have (and possibly teachers to develop) for MbL is so important. She acknowledges this in saying that

**a good way to start educating and supporting teachers to implement MbL or any other approach that moves away from their traditional practice is by allowing teachers to experience ‘diving into unknown situations’ [...] and] use this experience to reflect upon and refine their practice.”** (§40)

So to the question of who the learner is in the stories: Is it about children’s learning or teacher’s learning and if it concerns both what is the relationship between the two? Obviously it concerns all: teachers, children and even the researcher, who was also faced with some surprising results. I see this as a back-and-forth feedback process between
teachers’ own experiences with these kind of activities (as in Story 1), their reflections of – and motivation by – the unforeseen situations they have themselves the opportunity to delve into; the observation and reflection of students’ experiences (as in Story 2); and their involvement in designing a similar MBL activity (Story 3); all of which enriches the learning and professional development process for teachers. Papademetri-Kachrimani describes the reflective process as one that begins with a new problem/challenge that drives towards a new cycle of collecting observations and making representations [leading] the learner to construct gradually a deeper understanding of the phenomenon/structure/concept under study. (§33)

4 One thing that I find particularly important in this process is the role of representations, and the articulation between the ways in which the solutions are presented: e.g., as graphical representations and as equations. I very much appreciate that teachers are “encouraged to go backwards and forwards between what they actually saw and how they counted the circles in the shape and their representation(s)” (§14) in order to gain better understandings. Representations, either graphical, algebraic or in any form, are the produced shareable products that make this learning process constructionist. Furthermore, articulating and constructing links between representations is a fundamental component of developing meanings and understandings; part of what Richard Noss and Celia Hoyles (1996) refer to as webbing.

5 In conclusion, I consider that Papademetri-Kachrimani’s article is a helpful and interesting example of how teachers can experience valuable professional development experiences for future MBL/ constructionism implementations in their practice. Furthermore, it includes a profound analysis of the processes and the role of representations that can lead to the development of understandings in teachers, students and also researchers. A further possible step in terms of the specific activities presented could be to ask participants (whether teachers or students) to write some kind of computer program that puts into action the rules and strategies for counting that they described during the activities (i.e., to program the model created).

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Received: 8 June 2015
Accepted: 19 June 2015

Elements of Surprise in Teaching and Learning
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Upshot: In my commentary, I focus on the concept of surprise underlying the design of the learning experience presented in Papademetri-Kachrimani’s target article. I treat surprise as a concept that integrates the creative, open and non-predictable characteristics of constructionist teaching and learning. In my analysis, I show that current technological and societal developments have made these ideas of constructionism more relevant than ever. Within this rendering, it becomes clear that there is a need to revisit the position of constructionism in education.

1 In her target article, Chrystalla Papademetri-Kachrimani mentions the element of surprise as a principle that underlines the design of the learning experiences described. Furthermore, surprise in this article is not just a design choice. Instead, it is presented as a core element of a pedagogy that is not guided by a strictly defined curriculum (objectives, learning scenarios) and that places more emphasis on the rich, complex, dynamic and non-predictable nature of teaching and learning.

2 In this sense I find “surprise” relevant to the constructionist and to the constructivist approach to education. Both, by postulating that knowledge is actively constructed through the child’s interaction with the world, emphasize teaching not just as a process of directing learning towards a strict known end but as a process of offering opportunities to kids to engage in hands on explorations that fuel the constructive process (Ackermann 2004: 18). In constructionism, the constructive process of learning evolves around constructions with personal meaning for the learner (Papert 1980b), and is mediated by digital tools that empower learners to shape, express and share their inner ideas in and through their constructions (Ackermann 2004).

3 Constructions – being sand castles or theories about the universe (ibid) – as public entities to be shared and discussed, integrate elements of art that relate not only to the end product (i.e., the construction) but also to the process: the art of learning how to learn (ibid). Teaching and learning as art of course can refer to and make use of a framework (a set of goals, objectives and directions) but it also creates a space for surprise, for creativity and for freedom.

4 In Papademetri-Kachrimani’s article and in this analysis, a set of core ideas of constructivism and of constructionism have been highlighted: learning as an active process as opposed to passive consumption of information; empowering learners to shape (internalization of actions) and express their inner ideas; focusing on learner-generated constructions that have the status of public artefacts in the sense that they are situated in a social space where they can be shared, discussed and re-shaped. These ideas, although not directly related to constructionism, have become prominent today in the world of technology, where tools with new characteristics are gaining ground.

5 The current technological landscape is populated with tools that empower end-users to design, modify, extend, evolve and share their artefacts. Many examples are encountered in, but not limited to, the field
of digital games. Around these empowering technologies a new culture emerged in which user activity incrementally shifts from consumption to participation and in which the distinction between users and designers is blurred (Fisher 2009). This shift takes place through a technologically mediated transformation of the user from a passive consumer of finished goods designed by some to be consumed by many to an empowered individual equipped with the means to participate actively in the produced culture. Such constructionist tools, along with innovations such as 3D printing, democratize production by lending users the power to produce high-quality goods (physical or digital).

« 6 » An important point to note here is that the use of tools oriented towards construction (from now on “constructionist tools”) is situated in the powerful social space of virtual communities. Virtual communities are not just the space where members share and discuss their products. Instead, they constitute a learning environment that offers the support and the collective intelligence necessary for individuals (as opposed to companies or experts) to deal with the demanding process of constructing high-quality end products. Characteristic examples are, to name a few, the “Do It With Others Communities” (an evolution of the “Do It Yourself” communities), the communities that develop and live around popular sandbox games (such as Minecraft) or around tools such as Scratch, the communities that organize events around technology and culture such as museumix (http://museumixuk.tumblr.com), etc.

« 7 » The characteristics of constructionist tools designed to empower end users, new materials and innovations (3D printing and automation), by democratizing production, have empowered communities to such a degree that a new direction in the design and production process is identified. This new direction involves shifting the orientation of design as a top-down process of producing rigid closed products to a process that entails the...

**activation of open systems, tools that shape society by enabling self-organization platforms of collaboration independent of the capitalist model of production.**

This new approach, built around tools, self-organized communities and constructionist culture, is related to the third industrial revolution and the concept of adhocracy (ibid).

« 8 » My reference to the broader technological and societal landscape aimed to show how relevant the ideas of constructionism have become today, which is partially explained by the wide availability of tools with affordances that empower end users towards constructions. This realization is particularly interesting if we consider that the current trend in educational research is guided towards:

- micro-learning: i.e., focusing on more effective consumption of content – due to the growing amount of content available; and
- big data, data analytics, personalized and affective computing: i.e., focusing on over-structuring the teaching and learning process by recording and modeling as many aspects of student activity as possible.

In this context, quite often we see the use of sensors to capture biometric data (breathing rate variability, skin temperature, blood oxygen saturation, etc.) mobile data, mood data, social activity data (for an overview see Ferguson 2012). These data are labeled to model student behavior; the constructed models are used by technology to regulate student behavior towards other desired modeled behaviors or towards specific learning objectives; then new data are produced by the students feeding back into the “vicious” cycle.

**Out of the maelstrom of happenings we abstract certain bits to attend to. We snapshot these bits by naming them. Then we begin responding to the names as if they are the bits that we have named, thus obscuring the effects of change. The names we use tend to ‘fix’ that which is named […]**

(Postman & Weingartner 1969: 105)

1 | For a list see http://lifehacker.com/the-best-free-tools-for-making-your-own-video-games-1689905461


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Received: 6 June 2015

Accepted: 17 June 2015
Author’s Response: School Reform: Is it indeed impossible?
Chrystalla Papademetri-Kachrimani

> Upshot • Building on the commentator’s responses to the target article and bringing together all the valuable arguments, I pin down the challenges raised by reconsidering the concern Papert had at some point that school reform is impossible.

1 Ana Isabel Sacristán pinpoints the deep connection between modeling-based learning (MBL) and constructionism and affirms that the first is a form of the latter. At the same time, Nicoleta Yiannoutsou highlights a number of powerful technological communities using “constructionist tools” and bringing constructionism to life. Taking these remarks one step further, I would like to pinpoint the deep relationship between MBL, constructionism, and the Reggio Emilia Approach and support that the latter is (even though not about computers) a learning community bringing together the first two (MBL and constructionism). As I will elaborate further on, this connection is of a fundamental significance for many of the discussions within the constructionism community as well as for the issues raised by Sacristán and Yiannoutsou in their responses to the target article.

2 As a scholar coming from the perspective of early childhood education, I could not have been but inspired by the Reggio Emilia Approach, as I was inspired by constructionism. The common convictions between the two were quite apparent. But I was delightfully surprised when I became aware that people coming from the constructionism community (but not directly from the domain of early childhood education) had identified the same connections as I did (even before I did).

Perhaps the most outstanding implementation of constructionism may be found in the more than thirty infant-toddler centers and preschools in the Italian city of Reggio Emilia. (Stager 2012: 111)

But for me, the most impressive part of the Reggio kindergartens is the way they encourage children to reflect on what they are doing. Children in Reggio are constantly producing drawings and diagrams as they work on projects. Teachers use these artefacts to engage the children in discussing and reflecting on their design process and thinking process. (Resnick 2007: 5)

3 In trying to identify “What can we learn from Reggio Emilia,” Lilian Katz (1998) pinpoints all those aspects of Reggio Emilia that make it an approach that brings together MBL and constructionism (even though this was not her intention and no reference is made to either).

The first major lesson from Reggio Emilia is the way their young children are encouraged to use what they call graphic languages and other media to record and represent their memories, ideas, predictions, hypotheses, observations, feelings and so forth in their projects. Observations of the children at work in Reggio Emilia reveal how a wide variety of visual media are used to explore understandings, to reconstruct previous ones, to construct and coconstruct revised understandings of the phenomena investigated. (Katz 1998: 28)

4 But in this response, I would like to go beyond the apparent connections between constructionism, MBL, and Reggio Emilia and pin down aspects of Reggio Emilia that might help us towards an effort for school reform, an effort considered at some point by Papert (1997) impossible. This is despite the fact that Reggio Emilia cannot be considered as an example against Papert’s (1997) concern since it is an educational approach built from scratch out of the ruins of World War II.

5 As stated by Louise Cadwell (2003), two of the essential elements of the Reggio Emilia Approach are that the educators view (a) children as strong, rich, and capable and (b) themselves as researchers who consider the children also as researchers. Thus, everyone in a dynamic learning community should be learning together (the latter being one of the main claims of the target article) and, as both commentators stressed, “surprise” should be a key element of this learning process.

6 On a daily basis, in my work as a teacher educator, I work with “real” teachers, working in “real” schools, or I work with student-teachers who are placed for school experience in “real” schools. The adjective “real” refers to what actually happens in the educational system, which is indeed far from being the rich, powerful learning community many envision. So on a daily basis, I am faced with the same challenge: How do we support teachers to deliver rich, creative, dynamic, open-ended constructivism/constructionism learning? And how do we manage that this is the schools’ culture and not something they sometimes do during the week? We see it happening in research projects and within communities such as the ones Yiannoutsou refers to. We see it happening in computer clubhouses around the world (https://llk.media.mit.edu/projects/203/). But how do we manage to create this culture in schools? To create such learning communities outside the school has proven to be plausible, but how can we make schools into such learning communities and cultures? Should we just accept that school reform is impossible?

7 Papert (1997), has argued why school reform is impossible and has identified that the problem lies in missing that the whole point of the use of computers is to make everything change.

8 We should be talking about the opportunity offered us, by this computer presence, to rethink what learning is all about, to rethink education. (Papert 1990: 3)

But in the case of Logo, one sees its absurdity by the fact that the whole point of Logo is to make everything else change. One doesn’t introduce Logo into a classroom and then do everything else as if it weren’t there. Such an approach completely misses the point. Logo is an instrument designed to help change the way you talk about and think about mathematics and writing and the relationship between them, the way you talk about learning, and even the relationships among the people in the school: between the children and the teachers, and among the children themselves. (ibid: 7)

8 Papert’s conviction that the major contribution of the computer presence was to help us rethink what learning is all about, to rethink education and schools, is of great

http://www.univie.ac.at/constructivism/journal/10/3/370.papademetri
importance. To find ways to help teachers rethink learning, education, and even their role as teachers is a great challenge. I value Sacristán’s statement supported by the literature that “teachers tend to teach the way they have been taught, with their beliefs about teaching and learning shaped by their own experience” (§3). So if we want to support teachers to rethink learning and education, we need to change the way we teach the teachers (the way teachers learn). Within the PLEGMA project, from which the stories of the target article derived, it seems that we managed to support teachers’ learning in a manner that allowed them to construct a reconstructed understanding of learning, which had a domino effect on their practice. 

§ 9 In a reflective study (Philippou, Papademetri-Kachrimani & Louca 2015), where we explored the experiences of 14 teachers who participated in a professional development (PD) programme as part of the PLEGMA research project, we became aware that what we achieved with the teachers was indeed what Papert (1990) aspires to from the presence of computers. We managed to help change the way the teachers talk about and think about mathematics, the way they talk about learning and the children, and even the relationships among the people in the educational community.

§10 In the conclusions of the aforementioned study, we concluded that...

“the kind of knowledge produced [through the participation of the teachers in the PD programme] remains a point of concern for us, as its descriptive articulation during the interviews rendered it rather tacit.” (Philippou, Papademetri-Kachrimani & Louca 2015: 397)

This came to my mind when I read Yianoutsou’s comment that language can indeed narrow down our view of the world. Maybe moving away from an effort to articulate in words the learning involved was another aspect of the PD program that allowed the teachers to construct an understanding of this new way of learning. But when asked to get involved in a curriculum development effort (leading to school reform), you are faced with another challenge. How do you articulate (in written language) a program that will lead to rich, powerful constructivism/constructionism learning without narrowing it down, without extracting its richness and power?

§11 As this response is coming to an end, and as the questions and challenges seem to be increasing, I would like to refer to another valuable lesson we gain from the Reggio Emilia Approach. As acknowledged by Cadwell (2003), one of the main lessons we can learn from Reggio Emilia is that in an effort to form an educational approach, one needs to be original.

§12 So the challenge I am faced with is not how to support MbL in schools, nor how to make schools in my country’s educational system into Reggio Emilia schools, nor to transform schools into computer communities. Inspired by all these paradigms, cultures, and approaches that share the same convictions, the challenge is to be original. Original in an effort to make schools into places where “hard fun” takes place that leads to “hard learning,” to return to the argument deriving from the stories of the target article. School reform! It is definitely a difficult task, a challenge. But should we give up and accept that it is impossible? How can one overlook the fact that children spend a great deal of time in schools, where they are supposed to be learning?

Received: 21 June 2015
Accepted: 28 June 2015

Combined References


Learning about Urban Sustainability with Digital Stories
Promoting Collaborative Creativity from a Constructionist Perspective

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> Context • Sustainability is among major societal goals in our days. Education is acknowledged as an essential strategy for attaining sustainability by activating the creative potential within young people to understand sustainability, bring forth changes in their everyday life, and collectively envision a more sustainable future. > Problem • However, teaching and learning about sustainability and sustainability-related issues is not an easy task due to the inherent complexity, ambiguity, and context-specificity of the concept. We are in need of innovative pedagogical approaches and tools that will allow us to design learning activities in which learners will be empowered to develop new, alternative interpretations of sustainability in personally and collectively meaningful ways. > Method • We argue that a constructionist perspective involving the use of expressive media for digital storytelling offers an appropriate frame for designing learning activities fostering collaborative creativity in thinking and learning about urban sustainability. Our study is based on the design of a learning activity following this rationale. We adopted a qualitative approach in the collection and analysis of different sources of data with the aim to explore collaborative creativity as a learning process based on the students’ collective processes and resulting in the co-construction of new ideas and insights about sustainability, and new tangible artefacts (the digital stories) encompassing them. > Results • Our analysis of the collaborative creativity exemplified in the three digital stories produced identified important creative elements with regards to the three components of a digital story (script, technical characteristics, and ideas of urban sustainability) and how they were embodied in each digital story produced as a result of the students’ joint constructionist activity. > Implications • Our study provides some preliminary evidence that collaborative creativity from a constructionist perspective can stand as an appropriate framework for designing learning activities addressing the difficult concept of sustainability. There are several implications for both theory and educational practice in environmental education and education for sustainable development, constructionism, and digital storytelling in education. Moreover, our study opens up new fields for research and theory in creativity. > Key words • Sustainability, urban sustainability, collaborative creativity, constructionism, digital storytelling, learning design.

Introduction

Constructionism has established itself as an epistemological paradigm, a learning theory, and a design framework, mainly in conjunction with the advent of digital media designed to be used for engagement with mathematics (Kynigos 2012). However, it has gradually passed into more disciplinary domains and their related educational fields, such as science education and information technology education. However, extending constructionist frames of thinking beyond these domains of knowledge, commonly-regarded as traditional “hard,” objective and value-free, to the social sciences, humanities, and the arts is a challenge that has never been taken up seriously (Daskolia & Kynigos 2012). This applies in particular to fields of knowledge and educational practice dealing with “soft,” value-laden, and elusive concepts and problems of our current reality, such as those labelled under the topic of sustainability.

Sustainability has been a core concept of environmental policy discourse over the last two decades (Hopwood, Mellor & O’Brien 2005) and among the key topics of most education curricula worldwide (UNESCO 2005). Designing and providing learning experiences with a focus on sustainability is acknowledged as a prerequisite for young generations to gain a deeper understanding of current socio-environmental problems and become involved with the elaboration of plans to bring change to their everyday life and the world. To this end, pedagogical designs and tools have to be prioritized, with a focus on activating the stu-
students’ creative potential for developing new understandings of sustainability within the context of their current reality, and shared visions of a more sustainable future (Blewitt 2005; Daskolia & Kynigos 2012; Daskolia, Dimos & Kampylis 2012; Wals 2010).

« 3 » So, how can constructionism lead the way in designing learning situations fostering the students’ creative engagement with sustainability issues? The study reported here is used as an example of applying such a constructionist lens in teaching and learning about “urban sustainability” through digital storytelling. We argue that such a constructionist design entails a genuine pedagogical potential for enhancing collaborative creativity in students’ learning around and about the concept of sustainability.

« 4 » The three first sections provide the theoretical framework of our study. In the first section it is argued that there is an ongoing discourse over the concept of sustainability and most sustainability-related issues, which render them complex, elusive, and thus difficult topics to address on a pedagogical basis. New approaches and tools for teaching and learning have therefore to be explored, fostering collaborative creativity in thinking and learning about sustainability. In the second section, collaborative creativity is addressed from a constructionist point of view and a proposed definition is offered. Finally, the third section situates digital storytelling as an appropriate medium for boosting collaborative creativity and learning along this line of thought. The following three sections present the research design and focus of the study and describe and discuss the results. The final section of the article summarises the conclusions drawn from this study.

On the concept of sustainability and urban sustainability

« 5 » Over the last twenty years, the concept of sustainability has been closely associated with education. Learning about sustainability is acknowledged as an essential strategy for achieving sustainable societies and as a tool to enhance quality in educational practice (European Council 2010). However, there are inherent difficulties in dealing with sustainability from a pedagogical point of view due to its inherent complexity, vagueness, and context-specificity (Daskolia & Kynigos 2012).

« 6 » There is a plurality of meanings and interpretations assigned to the concept of sustainability, which are eloquently depicted in the more than three hundred available definitions counted by Andrew Dobson (1998) more than 15 years ago. As a means to overcome the lack of definitional consensus, there is some sort of agreement that sustainability can be thought of as bringing together three interdependent and overlapping systems: environment, economy, and society (UNESCO 2005). The proper functioning of all three dimensions is proposed as a necessary condition for achieving sustainability. However, there are differing, even competing suggestions as to what should be cared for, promoted, or avoided under each of these sustainability dimensions, with each of these approaches emanating from diverse disciplinary and/or ideological standpoints (Hopwood, Mellor & O’Brien 2005).

« 7 » The same complexity and indeterminacy applies when it comes to defining sustainability in every context and related issue, as in the case of urban sustainability. Contemporary cities are complex agglomerations of human-made and physical environmental systems, and as such they offer many opportunities for identifying and pursuing sustainability. However, there are different approaches as to what “a sustainable city” implies. Although many view it as an ecological entity, or as the extended version of an ecosystem (Newman 1999), the idea of the sustainable city has been worked on through various disciplinary and ideological lenses. This has led to a plethora of models on urban sustainability, all of them arguing for a systemic conception of all interconnected dimensions (social, economic, and environmental), while each of them places the emphasis on a particular operationalisation of it in terms of the issues involved and the necessary actions to alleviate them.

« 8 » The plurality and open-endedness of perspectives underlying urban sustainability undoubtedly renders it a “difficult” theme to teach. On the other hand, it is this relativistic “plasticity” characterising all sustainability-related concepts and issues that involves a particular pedagogical strength, if identified and properly treated: by refuting the existence of one correct interpretation, sustainability challenges learners to become engaged in creatively constructing “their own” understanding of it (Daskolia & Kynigos 2012). New approaches and tools for teaching and learning have therefore to be explored, allowing learners collectively to identify and define “sustainability” on their more proximate levels of their everyday life. We argue that constructionist designs of learning about “what living sustainably in a city” means can foster collaborative creativity in thinking and learning about sustainability. We also suggest that digital storytelling is an appropriate medium for boosting learning along this line of thought.

Collaborative creativity from a constructionist learning perspective

« 9 » There are many conceptual and theoretical overlaps between creativity and collaborative learning, and the borders between them are frequently blurred. Both concepts refer to shared meaning-making and knowledge-construction processes. From a constructivist point of view, novel or alternative ideas can be generated through a combination of individual and collaborative activities embedded in particular socio-cultural contexts (Craft 2008). Such an approach approximates the constructionist paradigm of learning, which gives learners a designer role, emphasises the importance of social participation and sharing processes in the knowledge-construction, and recognises the importance of designing artefacts that are of relevance to a larger community (Papert 1980, 1993; Kafai 2006).

« 10 » Constructionism places an overt emphasis on learners’ creative performance, expressed by the active exploration, construction, and modification of digital artefacts (Papert 1993; Kafai & Resnick 1996). Digital media and tools can be used by learners to construct meaningful objects as the tangible outputs of their meaning-making processes while they interact with them and the learning context; they are at the same time representations of their ideas.

http://www.univie.ac.at/constructivism/journal/10/3/388.daskolia
and understandings of the world (Kynigos 2007a). Equal importance is attributed to the mediating tools and the social context with and within which constructionist activities as processes and products occur. Distributed constructionism was the first attempt to focus on collaboration and discussion around and about constructions, either insights or digital artefacts (Resnick 1996). It was based on the idea of combining constructionism with distributed cognition, and addressing learning “not as a property of a person but as the process of interaction with others and the environment” (ibid: 281). Digital tools and social environments that allow learners to use them collectively in meaningful ways, to think collaboratively with them and discuss them, and to smoothly move from inquiry to playful activity, imaginative expression, and bricolage, are important coordinates of a learning context fostering collaborative creativity (Burleson 2005; Sullivan 2011).

Although we are in need of a more robust theoretical groundwork to understand collaborative creativity in general (Sullivan 2011) and from a constructionist perspective (Daskolia & Kynigos 2012), the existing literature allows us to define it constructively as the joint, intentional, and participative learning processes between members of a group (or community) of learners, which:

- take place within a particular socio-cultural and learning context;
- are related to a specific subject domain;
- can be aided by a range of mediating tools; and
- end up in the co-production of (a) new ideas, insights, and interpretations of the learning object, and (b) new tangible artefacts, which result from and encompass (a).

Our proposed definition is embedded within the general theoretical paradigm of “everyday” or “little c” creativity, i.e., creativity that is related to a potential all people are capable of displaying, and can be manifested in various situations of everyday life (Simonton 2010). It is more particularly based on two special cases of little-c creativity, namely “mini-c” creativity and “middle-c” creativity. “Mini-c” creativity refers to creativity in the learning process, which is inherent in the students’ unique and personally meaningful insights and interpretations of their experiences, actions, and events as they learn new subject matter (Kaufman & Beghetto 2009). However, our perspective also borrows from “middle-c” creativity (Moran 2010) by assuming that new understandings and products emerge within small communities and groups as a result of the collaboration, conversation, and joint thinking processes (Moran & John-Steiner 2003) that occur while they are tinkering with ideas and artefacts with the aid of mediating tools allowing expression and experimentation (Kynigos 2012).

**Digital storytelling as a tool for fostering collaborative creativity**

We identified digital storytelling as one such appropriate mediating tool for collective engagement in creative meaning-making processes on the concept of urban sustainability. But what is digital storytelling?

Alan Levine and Bryan Alexander (2008) define it as the practice of telling a story through the use of digital media. In technical terms, digital storytelling is mostly supported by short videos including images and/or video clips, soundtrack music, and/or narration, and also by media slideshows, interactive presentations, and hypertext embedded in Web 2.0 tools such as blogs, podcasts etc. In the classic model of digital storytelling, pioneered by the Center for Digital Storytelling in Berkeley, California, digital stories are narrated in the storyteller’s own voice. They are produced by using inexpensive, readily available software, with a focus on compressing the elements of the film into a short piece only a few minutes long (Lambert 2002).

Digital storytelling has been applied in a broad spectrum of educational contexts and in a variety of mediation mechanisms provided by new technology. In higher education only, the practice of digital storytelling spreads across a broad range of disciplines, from history and literacy/ESL studies, to knowledge management, business and leadership, community planning, psychology, gender studies, social and cultural history, and much more (Benick 2012).

Nevertheless, there are very few applications of digital storytelling in the service of interdisciplinary domain learning, such as in the context of learning about sustainability.

When more than one person is involved in the practice of digital storytelling, then we refer to either group storytelling (Benick 2012) or collaborative storytelling (Gabriel & Connell 2010). Flávia Santoro and Patrick Brézillon (2005) define group storytelling as a collective sense-building activity, during which many individuals contribute their ideas and interpretations of a shared repertoire of experiences. Yan-nis Gabriel and Con Connell (2010) refer to co-created stories, stories that are created simultaneously as different people interact and add specific elements to the narrative; thus the person who introduces a dilemma or a choice into the plot is not the one who has to decide its outcome. Joint story construction supported by collaborative constructionist principles, is also put to use by Inmaculada Arnedillo-Sanchez (2008) and Mike Sharples et al. (2009) using mobile learning technologies.

Finally, from a constructionist point of view, collaborative storytelling is the collective creation of a meta-story from individual stories constructed in parallel (Freidus & Hlubinka 2002). Along this line of thought, stories become objects to think with, i.e., constructs that evoke reflection, negotiation and dialogue, involving and inducing new ideas and understandings. Their quality ameliorates as the dialogue progresses, and as successive versions are presented and exposed to an in vitro audience, i.e., the other groups within the community. It is therefore almost by definition that the co-construction of a digital story is a collaborative creative learning process and a product by itself.

**The context of the study**

The study reported here was conducted with three small groups of Greek undergraduate students. They were all participants in a workshop entitled “Learning about urban sustainability through collaborative construction of digital stories,” which was organised in the context of an introductory foundation course in environmen-
tional education offered by the Department of Pedagogy of the National and Kapodistrian University of Athens (Greece).

The design of the workshop was to engage students in collaborative constructionist activity entailing sharing, reflecting, and combining their ideas and interpretations of sustainability with their experience and visions of living in Athens while they were designing and constructing their digital stories. Two educators (the first and the third author of this article) were in charge of designing and running the workshop. They were assisted by a post-graduate student in environmental education, who acted as a moderator and note-keeper for the sessions, while also conducting her master’s thesis research on this topic.

The workshop was carried out in six 3-hour (face-to-face) sessions, which were structured around:

1. Progressive discussion and negotiation of ideas on the concept of sustainability and in particular sustainability in the city, and
2. The digital literacies needed to create digital stories, such as the synthetic skills needed for the composition of a multimodal construct (multimedia authoring, including sound, video and image processing).

Apart from the face-to-face sessions, which took place in the computer room of the Educational Technology Lab of the Department of Pedagogy, the students participated in tasks that involved use of the electronic platform of the University (e-class), and met several times outside the context of the workshop to work on their joint tasks. The whole duration of the activity was 2.5 months, from early April until mid-June 2013.

Eight (8) female and three (3) male students in their third and fourth/final year took part in the study, allocated into three groups of three to four students. The instructions given to them were that their digital stories should:

1. Organically integrate all individual members’ ideas on sustainability,
2. Be short (up to 3 minutes), and
3. Be made with inexpensive, readily available technology (for this, Windows Movie Maker was selected as a low-cost and user friendly option).

This has been termed the “home made” approach to NLE (narrative learning environments), including examples of such environments that make use of general purpose technology and envisage some narrative task within the overall design of a learning activity (Dettori & Giannetti 2006).

The assistance provided by the educators/researchers to all three groups was in terms of progressively helping them develop their subject-matter and digital literacies as a prerequisite for getting involved with collaboratively constructing their digital stories and in supporting them to establish a good climate of collaborative work. Issues of work organization, choice and use of media, story construction, and application of knowledge on sustainability were all dealt with within the groups.

The products/artefacts, both digital and non-digital, produced and/or used by the three groups during this constructionist activity were:

1. Photographs taken by students, and used as primary material for a first draft of their digital story;
2. Concept maps, as representations of the group’s ideas on urban sustainability;
3. Story scripts, in the form of written texts;
4. A “contract of good collaboration,” including basic principles on group collaboration, defined by the groups themselves; and
5. Digital video files, as drafts of the digital story in progress.

Each session included either the initial drafting or the improvement/negotiation of one or more of the above materials. These products, thus, evolved in parallel to the participating students’ ideas and provided different ways of representing jointly-negotiated meanings on the theme of urban sustainability at different stages of synthesis.

Research focus and method of the study

Our research interest in this qualitative study focused on exploring collaborative creativity as a learning process, having led to the students’ generation of:

1. New ideas and insights about the sustainability concept, and
2. New and meaningful tangible artefacts (the digital stories), which are viewed as both the outputs of the learning process and the students’ representations and understandings of the sustainability concept.

Our approach thus puts forth a constructionist perspective of collaborative creativity as an activity occurring within a learning context that involves and results in the generation of new understandings and tangible artefacts on the sustainability concept (new, at least for the students themselves), along with their collaborative construction of the digital stories.

Two categories of data were collected:

1. Data on what was orally exchanged during the sessions, and
2. Data on what the students constructed.

For (1), data included transcripts from all recorded sessions, the focus group interviews, the online discussions in e-class, and the researchers’ observation reports. For (2), data included the successive versions of the digital stories produced, and all the material brought in or produced by the students as an input to their digital stories (the photographs taken by the students, the groups’ concept maps on urban sustainability, the story scripts, etc).

The units of analysis were:

1. The idea on (urban) sustainability, and
2. The digital story as the final product.

Data were analysed according to emerging themes in the students’ shared ideas and representations of the sustainability concept for each group case across all data sources, in each specific category of data separately, and in various combinations of data sources. In this article we present the findings from the analysis we carried out in the digital stories produced out of each group’s constructionist activity, combined with the notes taken throughout the activity by the researchers and the data gathered from the focus group discussion conducted with each group, which took place in session 5. However, we treat the three groups as one single case and not as three separate ones.

How is collaborative creativity manifested in terms of new ideas and un-
understandings generated out of the groups’ collaborative processes, and embodied in the digital stories produced, each of them viewed as a constructed learning object encompassing (a) a script, (b) a technical, and (c) a subject-domain (“urban sustainability”) component?

In the following section we present and discuss our findings for each digital story separately. The headings for each subsection are the titles given by each group of students respectively (Group 1 to Group 3) to their digital story. All quotes used in the text are taken from the focus group discussions that took place in session 5.

Findings and discussion

“La vie en vert”

The digital story created by Group 1 is about a flower growing in some place in a big noisy city, with no sun and water, and suffering from pollution caused by exhaust fumes and people’s littering behaviour and neglect. Some hope appears when a group of children adopt it and save it, and so the flower lives happily ever after, along with its newfound friends.

On a first glance, the story appears oversimplified. However, the group’s collaborative processes in devising and displaying a story that is satisfactorily “creative” to their standards and faithful enough in representing their idea of sustainability in its full meaning and complexity is quite interesting.

Actually, this is the second story this group produced. The first one was a totally different digital story that was based on their initial idea to combine the photos they had taken from their city into a coherent set, which they then tried to articulate in a video based on a script about a homeless man who is given a second chance in life through appropriate measures taken by the state and the concern of some supportive citizens. This first try, however, did not satisfy them, as they thought it covered only the “social” aspect of sustainability. An important factor also contributing to the rejection of this first draft was the group’s frustration with the affordances of Movie Maker as a tool.

In their second effort, the group started using animation software and developed a new script which led them to the final version with the flower. They spent many hours using professional image editing software to make different still frames that would give the impression of a moving graphic. They finally came up with two animated frames and complemented the story with still graphics of similar aesthetic style. It could thus be claimed that the group’s history of constructing their digital story embodies their experimentation with a range of technological tools and domain ideas on the concept of sustainability in an effort to attain their desired final product.

In technical terms, the second digital story is an interesting amalgam of still graphics, photo-collage and animated graphics. There is a soundtrack and no oral narration, the latter substituted by successive text legends appearing middle screen between each graphic, illustrating the evolution of the plot. The story is conceptually divided into two units: the first including graphics in black and white to accentuate the ambience of the flower-hero’s time of misfortune, and the second including graphics in vivid colours to depict the flower-hero’s twist of fate (see Figure 1, top and bottom succession of scenes). The characters, as well as the name of the city, are not specified. An equally abstract script, consisting of few short phrases, reinforces this vague context.

This group’s conceptualisation of sustainability in the city also developed from their first digital story to the second. They actually moved from an interpretation related almost exclusively to a social indicator of urban sustainability, homelessness alleviation – a traditional “hard” social sustainability theme (Colantonio 2010) – to an expanded conception, encompassing more environmental but also some social and economic concerns. This transition from a one-dimensional to a more holistic view of sustainability is an indication of a “creative” learning act, which resulted from the students’ discursive processes while tinkering with their digital story:

Figure 1 • Selected frames from the digital story of Group 1.
In our first story we were talking about only one aspect of sustainability. However, sustainability goes through three dimensions: economy, society, and environment... In the first story we were more focusing on society. We were showing a person who was alone and homeless. However, in this second story we have recasted, we have profoundly re-constructed our concept to have all three sustainability aspects present.** (Excerpt from the transcribed focus group interview)

What both stories share in common is that they start from ascertaining a lack of sustainability based on the identification of specific socio-environmental problems. However, the first story focused on one striking social issue of contemporary cities, while the second speaks of more problems, and more environmentally-focused problems (air and noise pollution, waste, overpopulation and urban density, and lack of green spaces). Both digital stories try to end with an optimistic message and call, without neither of them avoid some naïve over-simplification (“the solution lies in our hands,” “tree-planting as a solution to the problem”). It is interesting, though, to see how the very experience of collectively searching for the meaning of sustainability shaped their understanding into propounding the adoption of collective action as the main roadmap to sustainability (Roseland 2012). They are also aligned with a view of sustainability as a future-orientated scheme of action, to be succeeded at if youth generations unite their visions and efforts to bring about change (Norton 2005). This, they argue, is their responsibility to the generations to come:

**The future is in our hands! The way we have conceived and made our story is that a better future lies in the new generations. We believe that it is in our hands to bring subversion. Sustainability is connected to the future.** (Excerpt from the transcribed focus group interview)

Although collaboration was not always balanced within this group, no explicit incidents of mistrust or conflict were witnessed. However, two group members, a boy and a girl, showed a greater degree of involvement in the whole task, in terms of both communicating their ideas on sustainability and constructing the digital story. This may be due to personality traits (they were evidently more self-confident and extrovert) and to a greater degree of media literacy, a fact also acknowledged by the other group members.

“A dream-road in hurdles”

The digital story of Group 2 is staged in the city of Athens, where, on a beautiful morning, Alexandra, living in Piraeus with her toddler son, Orestis, decides to join her cousin and her toddler daughter, Charis, at a playground park located in the area of Zografou. Their route to Zografou appears full of obstacles for a mother pushing a stroller, an image deteriorating through broken pavements and litter thrown all around. Fortunately, the park is in a much better condition, despite some garbage thrown carelessly on the ground. The mothers discuss the state of some areas of the city, but are compensated by their children’s joyous play at the park.

In technical terms, this digital story is a multimedia synthesis including photographs taken by the group members, a soundtrack synchronised with narration, and three videos recorded using Google Earth and inserted in between the photographs. There are two creative practices invented by Group 2 and reflected in their digital story: the first is the use of Google Earth as a device to indicate movement from place to place; the second is the use of role-playing. As the group’s story progressed in their script, they became aware that they needed actual people in their photographs. As getting consent to take pictures of mothers and children is a delicate issue, they decided to impersonate the characters of the story themselves.

With regards to the idea of the sustainable city, the group tried to offer a balanced representation of sustainability by projecting various dimensions of it, highlighting different problems everyday people face in a big city, while not leaving aside...
the bright side of urban life. A core theme in their conceptualisation of urban sustainability is that there are various contradictions inherent in a city, emergent in the different experiences of living in the same city (Milgram 1970). This is depicted in their story as the hurdles their heroes are confronted with while taking an everyday walk in the city, hurdles for which they blame the lack of infrastructure and state welfare. However, this problematic view of the city is compensated by the beautiful green public places designed for recreation and socialising that the students had identified and captured in their photos as good examples of sustainability in their city.

«42» Displaying complexity in a city’s life is interwoven with the students declaring uncertainty about how to define sustainability. They deliberately address this question back to their audience when closing their story, with the aim of instilling deliberation and reflection (“is your city sustainable?”).

«43» However, while declaring there is indeterminacy regarding the boundaries of sustainability, the students consciously focus on one aspect of it – quality of life – instead of trying to encompass all aspects of it within the limits of a short digital story:

S1: “Sustainability! Such a huge issue... It’s impossible to talk about all aspects in a 2.5 min video...”

S2: “Moreover, we thought that if we tried to put everything into our story, our message would risk getting lost.”

S3: “We tried to focus on only one aspect of sustainability. In one video you can’t say everything there is to say.”

R1: “Did you try to convey what is closer to your own view of sustainability?”

S2: “Yes. And also combine them with what we actually met and realised out of the investigation we conducted.” (Excerpt from the transcribed focus group interview)

«44» The students therefore used “quality of life” as an organising theme (Van Kamp et al. 2003) to bring various current sustainability issues to light, such as ease of access and transportation, efficient waste management, adequate infrastructure provided by sufficient state welfare, and proper distribution of green spaces and public spaces for recreation and socialising in the city’s system.

«45» What is finally worth noting in their view is that sustainability starts from and ends with people’s awareness of the faults of their city, and their concern to change them to bring forth sustainability:

R2: “What is your aim if your story were addressed to a larger audience? What is the message you want to convey?”

S1: “To make people more aware of […] their city. Do they like living in a city like the one we are showing them?... To become concerned (the people) about how to change it to make it better. Actually to get involved (the people) with how to make their city to meet their standards of living and how to better serve their needs.” (Excerpt from the transcribed focus group interview)

«46» Collaboration within this group was characterised by a shared vivid interest in the task and a sense of complementarity. Mutual engagement seems to have resulted from the degree of negotiation of ideas at all levels, but also from the members’ openness to alternative ideas and suggestions. Every decision was taken by all members, after articulating and sharing all proposed alternatives. There were arguments and counter-arguments, but no issue was left unresolved.

“It happened in Elefsina...”

«47» This group created a digital story about a young student coming from a well-off family and very much concerned about sustainability issues. Vassilis was also a member of an environmental NGO. When his father, owner of a small factory in Elefsina (an industrial area on the outskirts of Athens with many archaeological sites), announces his decision to build another industrial plant right next to the archaeological sites, already suffering from corrosion caused by the air pollution, Vassilis has a strong argument...
with him. His father, though, puts him in a dilemma, arguing in favour of more profit for the family, increased productivity, and the creation of new jobs for the locals. The solution for Vassilis comes quite effortlessly, since his father's plans are cancelled because of the economic crisis striking Greece. Vassilis then, with his friends from the environmental NGO, undertakes the reforestation of the area next to his father’s factory.

In technical terms, this digital story is a homogenous multimedia synthesis using the graphic element of comics (with no speech bubbles) and music synchronized with narration (from three successive narrators’ voices). It comes from their decision to use an online comic maker (Pixton) after experimenting with other alternatives. Their first draft was a video made with their own photos. However, they were not very satisfied as they had already begun to shape the story of Vassilis, which needed actual actors and settings. A first idea, supported mostly by one of the members (a girl), was to use a video of themselves acting out the story and then edit the video with professional software. The group rejected this idea as overly ambitious and time-consuming, and proposed the use of Pixton as an alternative. After some turbulence and disagreement, the members agreed on this solution and worked on their final draft in a rather cooperative than collaborative fashion. They assigned each member to work on a number of frames in a rather cooperative than collaborative fashion. They assigned each member to work on a number of frames online in Pixton. This was an asynchronous activity that led to the pre-final draft. Then they made final, commonly-agreed changes and synchronised the sound and narration.

The group’s idea of sustainability also evolved from initially adopting a rather naturalistic approach, to proceeding further to a more socio-environmentally and economically balanced view of current reality. Moreover, the students tried to address various aspects of sustainability and to talk about awareness, participation, and collective action as important prerequisites for attaining sustainability.

One interesting feature of their conceptualisation of sustainability was their idea to relate it to actual contexts (Elefsina) and situations from their everyday reality. They went a bit further, to view sustainability as connecting with the outer-burst of Greece’s economic crisis. A genuinely imaginative element in their thought was the idea that a crisis is connected not only with negative outcomes but also with opportunities for attaining sustainability in the other two dimensions, a suggestion also supported in the literature (Schneider, Kallis & Martinez-Alier 2010).

S1: “The most important thing is that the way we thought our story to deploy is by connecting it with our current reality. We used our current reality, we identified real facts and situations, we talked about the economic crisis, we put dilemmas regarding nature protection and new jobs... These are facts we come across in the cities nowadays.”

S2: “We have integrated our story in an everyday context of Athens. It is very close to our reality.”

(Excerpt from the transcribed focus group interview)

Another noteworthy element of their approach towards sustainability is the recognition that it is connected with the existence of some hard-to-resolve dilemmas (Bugliarello 2006). The students actually focused on such a dilemma: “Should we adhere to economic development through industrial expansion leading to the creation of new job opportunities, or should we prioritize the protection of the natural environment and cultural heritage through restrictions placed on industrialisation?" However, although they thought of and posed this dilemma, they did not avoid applying some simplistic and overoptimistic suggestions as to how to tackle it.

An impression of a satisfying level of collaboration within the group was initially given. However, midway through the project, some observed incidents of misunderstandings and communication failure disturbed the flow of collaboration. These can be attributed, at a first level, to a member’s persistent character and tenacity towards an idea the other members did not seem to embrace (the video shooting). At a second level, there seems to have been previous conflict among two of the group members before embarking on this collaborative endeavour. It is important to mention, though, that all members of this group expressed and supported their ideas, despite tension and disagreement at times.

Conclusion

Our study provides some noteworthy evidence that collaborative creativity viewed from a constructionist perspective can be used as an appropriate framework for designing learning activities addressing the difficult concept of sustainability. It has been designed and tried out with the aim of assisting in gradually developing a theoretically firm and practically enriched lens of how to turn the inherent complexity, elusive nature, and context-specificity of a sustainability-related issue into a pedagogical advantage. Of course, the evidence provided by this study, although promising, has to be taken as still pending on a preliminary basis, while more research is absolutely necessary before any sufficiently supported claim is put forth. Nevertheless, it can be claimed that our present endeavour adds to a substantial argumentation for the need for and value of expanding the realms of constructionism beyond those of mathematics, science, and technology education to the interdisciplinary fields of social sciences. However, as already noted, this is an early and still immature effort towards developing a steady theoretical framework on this question, and it needs to be buttressed by many more cases of implementing it in practice and studying it empirically.

For the construction of digital stories about urban sustainability has proven to be a demanding venture. It entails, for researchers/educators, although not presented here, the use of techniques for inciting and maintaining inspiration and supporting collaboration within the groups as well as the invention of mechanisms to shed light onto the practices employed and the artefacts produced. What is worth noting about the outputs of the process is the variety of digital tools used to construct the digital stories and the diversity of techniques employed by participants to grapple with the constraints and trade-offs of available digital resources and time limits.
prerequisite for devising their story scripts and for deciding on several technical and aesthetic features of their created artefacts. These ideas and insights are attached to a wide array of approaches to urban sustainability, which need to be further analysed and discussed as to their epistemological status and ideological origin. However, this was not within the scope of the analysis reported in this article. What we tried to address here was the produced outcomes (the digital stories) of these processes through their three constituent dimensions: the story, the technical characteristics, and the conceptual representation of urban sustainability as the main construct involved.

Further research could shed more light on the ways specific ideas on urban sustainability evolve in the course of constructionist activities that make use of expressive media for co-construction of meanings as the process and products of a creative learning process.

Acknowledgements

The research leading to this article was partially supported by National and Kapodistrian University of Athens (NKUA), under the annual Research Funding Scheme (4th General Assembly Decision of the Department of Philosophy, Pedagogy, Psychology, 21 December 2011) – Project title: “Designing learning activities to foster creativity with the use of digital tools.”

The authors would like to thank Rea Florou, postgraduate student at the time of carrying out the study, for her assistance in running the workshop and for her contribution to data collection and analysis as part of her Master’s thesis research. Comments by two anonymous reviewers greatly helped to improve an earlier version of this manuscript.

Received: 22 February 2015
Accepted: 29 May 2015

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Open Peer Commentaries

on Maria Daskolia et al.’s “Learning about Urban Sustainability”

Studying Complexity: Creativity, Collaboration and Learning
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> Upshot • Creativity, collaboration and learning are fascinatingly messy and interconnected processes. Does knowledge develop by engaging in a collaborative creative process, or does existing knowledge allow us to create more creative artefacts? Does one build upon the other in a bricolage process, familiar to constructivist learning experiences? If so, how can we best facilitate this type of learning? This OPC raises a number of questions that it does not attempt to answer but raises them to draw attention to the complexity of the phenomena under investigation.

1 Maria Daskolia, Chronis Kynigos and Katerina Makri's target article presents an example of constructivist principles employed to provide the theoretical foundation for a learning experience designed to provide learners with an opportunity to develop their knowledge and understanding of the conceptually complex area of "sustainability." Rather than employing a simulated environment or microworld for learners to explore and develop their own explanations of the outcomes they observe, the creation of digital stories asks the learners to consider in a personally meaningful way the micro impact of macro systems they have previously been introduced to, whilst simultaneously developing their understanding of the complexity and interconnected nature of these systems.

2 Three complex and interconnected areas are encountered in this article: creativity, collaboration and learning. Daskolia, Kynigos and Makri suggest that "a constructionist design entails a genuine pedagogical potential for enhancing collaborative creativity in students’ learning" (§3), taking a mini-c and middle-c approach to creativity, asking the question:

3 The key component of this question and initial statement of potentiality is "collaborative creativity." Collaboration is often confused with co-operation, when learners act together to achieve personal goals. While in collaborative activities, learners work together on a single-shared goal, creativity is an often intangible concept: it can be as difficult to identify a creative act or artefact as it is to identify the process through which it occurred.

4 Creativity has long been associated with learning (Guilford 1950), but how to identify creativity is often contested as there is no single definition of creativity that is agreed upon across and even within disciplines (Kleiman 2008). Commonly, there are three clear aspects of creativity discussed in the literature: the person, the process and the product. Particularly relevant to this article is the fact that design is often a collaborative and social process involving groups of designers (Warr & O’Neill 2005). These ideas and concepts are shared (with or without the support of physical artefacts) and both the creative process and creative product become socially mediated, which is reflected in the findings of this article. However it also raises important questions about Group 3, who are characterised in the article as co-operating rather than collaborating. What are the implications for creativity and in turn the co-construction of knowledge? Does learning occur at the individual level or at the level of the group?

5 Focusing on the design, it is interesting that each digital story in this article presented a problem scenario to be resolved (which was not a requirement in the initial brief). To begin with, a problem is a common aspect of models of creativity that not only prompts the generation of ideas but allows learners to evaluate their ideas. Andy Warr and Eamonn O’Neill describe the idea-generation-phase, which follows the analysis of the problem, as "the more specifically creative phase of the creative process model" (Warr & O’Neill 2005: 121). From a constructionist perspective, it is likely that it is at this point in the creation of the digital stories that learners take ownership of the project and it becomes personally meaningful: a powerful constructionist idea. Therefore if learning is associated with creativity, it is perhaps the initial development of the problem and generation of ideas that need to be examined in depth.

6 The creation of knowledge artefacts is a key feature of constructionist learning activities. They need not be final, as they are created to explore, test and extend understanding. It can be anticipated that these artefacts may be developed or even destroyed and created anew to encompass new/developing knowledge and understanding. For example, it appears that Group

http://www.univie.ac.at/constructivism/journal/10/3/388.daskolia
I created their second digital story for just this reason, stating that their first digital story only addressed one aspect of sustainability whilst the second covered all three. However, it is unclear whether this is development of knowledge through collective engagement with a creative act, or whether this was knowledge they already held that they used to develop a more creative artefact.

"7" I would argue that there may be evidence of both within the one group’s work and it is essential to examine the discussions between students to help illuminate this process of moving from one to the other. It is also worth considering how much of the creativity was driven by the technology and how much by collaborative knowledge construction.

"8" To explore the complex interconnected nature of creativity, collaboration and learning, it is also essential to understand the wider learning context in more detail. Real-world (non-lab-based) learning environments are messy places for research. It is this complexity that the educational researcher must relish if we are to develop the initial insights gained from this study further. Case studies are particularly powerful for developing an understanding of phenomena under study as they provide a rich description that researchers and educators use to inform their understanding of the implications of the research in their own contexts.

"9" One aspect of this study that remains unclear is the content and timing of the taught component of the module. There can be no assumptions as to what concepts were covered, what examples were given or even the mode of instruction. There can also be no assumptions made as to the level of student engagement in this more traditional section of the module, nor what they have learned from it. In developing this study, it would be valuable to consider whether the discussions that occurred as part of the workshops would have usually taken place in seminars (with no knowledge artefact created) and if so, would the same level of conceptual development have been achieved? This leaves us with some important questions: What is the role of existing knowledge in any apparently creative process or final artefact and does this mediate whether or not it is actually creative? Finally, considering the research question that is the focus of this study: Are “new” ideas and understandings generated and to what extent are they new at a group and individual level?

"10" The work of Daskolia, Kynigos and Makri demonstrates one way in which educators can support their students to develop these new understandings through constructionist learning activities, simultaneously providing researchers with several routes to explore the complex interconnected nature of creativity, collaboration and learning.

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Received: 8 June 2015
Accepted: 18 June 2015

Tool Selection and Its Impact on Collaborative Learning
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> Upshot • Daskolia, Kynigos and Makri’s article offers us a view into potential applications of constructionist learning theory to help students conceive of and collaborate on solutions to today’s complex problems. This work in many ways parallels the efforts of those investigating systems thinking and highlights the importance of digital production in that process. While many efforts rely on simulations and models, the authors place centrally the role of digital production in understanding complexity. This, in turn, calls our attention to the affordances and limitations of our current tools for facilitating learning and collaboration, and ultimately to the need for new tools.

"1" The expansive and often vague conception of urban sustainability is a particularly ripe area for exploration using constructionist means, given that constructionist learning is at its most efficacious when learners are brought together in a social context to create and share a personally meaningful text (cf. Papert 1980; Papert & Harel 1991) as well as illuminate “powerful ideas” such as sustainability and complex systems (Papert 1980). The approach explored in Maria Daskolia, Chronis Kynigos and Katerina Makri’s target article sits well at this intersection and helps expand the constructionist literature beyond the typical domains of science, computer science, and mathematics. In particular, their study helps us envision how this lens on learning and engaging with the world can shape our understanding of large, complex societal issues from within the domain of digital storytelling.

"2" Urban sustainability is a particularly powerful idea to explore, as it necessitates the awareness of and synchronicity between countless moving parts. In this article, the authors reference the three pillars that support most urban sustainability initiatives – economic, ecological, and societal concerns – and appear to challenge the students in their study not only to consider the interrelationships between these factors when collaborating on a solution to urban challenges, but also the most elegant way to represent these solutions in a short, multimodal narrative. A running thread through the group projects in this article, which included narratives about pollution and the environment, urbanization and public spaces, and the tension between eco- or historical preservation and economic growth, concerned the use of microcosm to symbolize the intersections of large, vast systems. Each group seemed to struggle at first to devise a project that acted as personal story, “issues” piece, and call to action. And, yet it was very clear in the end that each of these digital stories demonstrated an understanding that the circumstances of the individuals in their communities are shaped and influenced by greater systems in motion.

"3" An understanding of how systems like those depicted in these group projects work offers students a powerful lens for seeing, engaging, and changing their world (Jacobson & Wilensky 2006). There are numerous well-articulated approaches to teaching systems thinking in the classroom,
including the use of computer-based modeling (Colléla, Klopfer & Resnick 2001; Wilensky 1999), dynamic simulations (Colléla 2000; Danish et al. 2011), and connections to social and biological sciences (Jacobson & Wilensky 2006; Hmelo-Silver & Pfeffer 2004), to name a few. However, the vast majority of these efforts involve students exploring models of existing systems rather than designing their own. This article echoes the work of Linda Booth Sweeney and others, who have argued that stories can offer an important avenue into systems thinking for young people (Booth Sweeney 2001). Booth Sweeney’s work, in particular, calls our attention to the potential impact that stories have on our understanding of systems and traces a potential cause of our misconceptions of systems thinking to our children’s literature. She notes that many Western children’s stories exhibit linear causal thinking while there is a minority of notable stories that exhibit systemic ideas (e.g., Dr. Seuss’s The Lorax) that can be leveraged to help young people develop systemic outlooks important to sustainability. Daskolia, Kynigos and Makri harness the power of storytelling as a means to support systems thinking, conveyed through the constructionist activity of digital storytelling.

« 4 » One of the challenges that the authors cited in their study was the translation of the groups’ conceptual and narrative ideas into the technical dimension, the “digitalization” of their stories. The first group referenced in the article went so far as to change their project concept entirely because of their lack of familiarity with Windows Movie Maker, and members of the third group shot down an initial proposal from a team member to shoot and edit a short film because it would be too ambitious to do so. In constructionist learning, much attention is paid to the tools in use (in this case, the computer and the media applications utilized) and how the tool shapes our thinking (Papert 1980). In this respect, we see the impact that the range of media tools currently available for digital media production has on the idea construction and constraints of the learning space. Our choice of tools is important not only for their ease of use but also for their ability to support the design goals, in this case digital storytelling. In addition, many issues around sustainability and systems thinking are particularly apt to nonlinear and interactive forms of digital storytelling, which are particularly efficacious for digital stories concerning systems concepts.

« 5 » As part of an effort to promote systems thinking through engaging in design with digital media, we created a curriculum centered on digital storytelling using the Scratch programming environment (Pepper et al. 2014). Scratch is a media-rich visual programming environment designed to be an accessible space for young people to engage in the creation of interactive stories, video games, and simulations through the use of command blocks and drawn or imported media “sprites” (Resnick et al. 2009). Enabling interactivity in a digital story not only engages young people in major systems thinking concepts – including interconnection, system components, feedback loops, and leverage points – but allows the viewer similarly to have an impact on the storyline through their choices. Scratch’s particular affordances – remixing existing media, creating interactivity, non-linearity, and multimodality – made it an amenable environment for the creation of digital stories about systems. Moving forward, future research and development efforts should examine the impact of the tool on constraining and enabling the learning space. As evidenced by the three group projects in this article, the groups’ choice of digital storytelling tool shaped the projects in consequential ways, having a profound impact on the genre, narrative, and aesthetic of the story being told, as well as each group’s ability to collaborate in the design process.

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Received: 25 May 2015
Accepted: 22 June 2015

Narrative Learning for Meaning-Making, Collaboration and Creativity
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> Upshot: The target article by Daskolia, Chronis Kynigos and Katerina Makri shows the great potential of narrative learning to foster general learning skills, such as meaning-making, collaboration and creativity, while facilitating the construction of disciplinary content knowledge. This learning approach has much to recommend it, especially from a constructivist perspective, because it supports the implementation of collaborative and creative learning processes apt to promote reflective dialogue as a basis for knowledge construction, capitalizing on students’ previous knowledge and experience.

« 1 » The target article by Maria Daskolia, Chronis Kynigos and Katerina Makri provides an interesting example of narrative learning, and shows how this approach lends itself to fostering general learning skills while facilitating the construction of content knowledge. This is, indeed, the educational aim of these authors, who specify they have “a focus on activating the students’ creative potential for developing new understanding.” Let us see why the use of stories appears to be the right tool to achieve such a learning aim.

« 2 » Narrative learning consists in letting students make use of narratives of any kind (from invented stories to narrations of personal experiences), meaningfully related to assigned learning tasks. This approach to learning has been increasingly raising the interest of educational research because scholars of diverse orientations have recognized its learning potential, which derives from its characterizing features (Dettori Paiva 2009; Dettori et al. 2006). Narrative is a natural expressive form: from early childhood and throughout life, human beings appear to be endowed with “narrative intelligence” that leads them to naturally formulate and understand the meaning of stories (Bruner 1990; Mateas & Sengers 2002). Moreover,
people instinctively perceive the presence of causal and temporal relationships among narrative elements, which derive from their position in the narrative sequence (a co-
genent example is reported by Bruner 2004). In other words, stories work as meshes of interrelated ideas, each of which contributes to determining the meaning of the others as well as the overall meaning, thus helping to overcome the intrinsically linear nature of human discourse and combining richness of content with simplicity of form (Crawford 2005). Such perceived logical ties help lead people dealing with stories to grasp not only explicit but also implicit information, and consequently to engage in a meaning-
construction process (Bruner 2003), in particular in relation with their experience of time, cause-effect relations and personal actions (Polkinghorne 1988). This support to meaning-making is crucial to making nar-
Rative a powerful learning mediator. Stories, moreover, are based on actions and events; hence, they can stimulate learners to start reflection on concrete ground, avoiding the risk of producing abstract reflections not rooted in reality (Dettori & Lupi 2009). Stories help us to contextualize ideas, pro-
viding concrete examples and highlighting key elements. They can effectively support problem-spotting: as Jerome Bruner points out, narrative in all its forms “is an invitation to problem finding, not a lesson in problem solving” (Bruner 2003: 20).

All these aspects are clearly present in Daskolia, Kynigos and Makri’s described experience: the considered content knowl-
edge (urban sustainability) has a high level of complexity and includes a range of issues variously interrelated with each other with-
out any unique, predefined, best solution. The stories produced by the students manage well to spot a variety of concrete issues in the considered field. The fact that Group 1 ended up producing two stories suggests that the narrative form helped those students notice that they were considering only a small facet in the complexity of the field. Analogously, the endless discussions reported to have taken place in Group 3 suggest that during storytelling the students were gaining awareness of the complexity and intrinsic non-linearity of the field’s is-

Aspects such as the involvement of such affective / emotional aspects, being always close to the students’ life experience.

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Received: 24 May 2015
Accepted: 18 June 2015
Seeking “Power” in Powerful Ideas, Systems Thinking and Affective Aspects of Learning

Katerina Makri, Maria Daskolia & Chronis Kynigos

> Upshot - The commentaries raise a plethora of issues, extending the article’s problematic in insightful ways. In this response, we chose to focus on two interesting views on the “powerful idea” in the constructionist sense, on systems versus causal-rule thinking and on the affective aspect of collaborative learning.

« 1 » The concept of powerful ideas has been largely influential in the constructionist tradition, mostly, however, within the realms of science, computer science and mathematics. Having attempted to explore the contribution of constructionist frameworks of thinking to a greatly unexplored interdisciplinary field, education for sustainable development, in our theoretical position, we approached ideas in relation to their perceived novelty. By this we mean their potential to represent new or alternative meanings and understandings of the world, and the ways they were mediated in concrete digital artefacts. In our analytical position, we employed the idea of (urban) sustainability as a unit of analysis of our data. It is thus an inspiration for us to build upon two perspectives articulated by Carina Girvan (§5) and Kylie Peppler (§2) in their respective OPCs, to examine questions such as: What is “powerful” in an idea? How can constructionism help us explain the generation of meanings around such an idea, its use and its functionality?

« 2 » Peppler considers sustainability itself as a powerful idea, grounding the argument in the construct’s societal importance, complexity and systemic nature. As she eloquently states, “urban sustainability is a particularly powerful idea to explore, as it necessitates the awareness of and synchronicity between countless moving parts” (§2). For her, the constructionist challenge for students was first to reflect on the interrelationships among intersecting factors (economic, ecological and societal) and second, to invent a concise way to represent solutions multimodally but concisely, as a digital story. This, as a product, is interpreted as the result of an inductive process, from the macro to the micro level: starting from a personal story, “issues” piece or call to action and ending up in a representation of the students’ understandings of the relations between individuals in their communities and their surrounding greater systems in motion.

« 3 » Girvan, on the other hand, uses the term “powerful idea” in the context of creative design (§5). On the basis of her observation that all three digital stories presented a problem scenario to be resolved – though not a prerequisite set by researchers for the task – she pinpoints a common element in constructionist and creativity literature: the importance of an open problem as a trigger for both constructionist and creative outcomes. An ill-structured problem (Jonassen 1997) triggers constructionist activity because it allows exploration and experimentation without guidance by typical, predefined rules; and it triggers creative activity because it facilitates the generation and evaluation of ideas. In line with a dynamic tradition in creativity literature, represented by process models, the idea generation phase following the analysis of the problem is crucial for achieving creativity. The same phase is equally important in constructionist learning activities: it is the key moment of taking ownership of the project at hand and starting to develop personal meanings, an appropriation of instruments and meanings, as discussed by Chronis Kynigos (2007b) and Anne Fuglestad et al. (2010). This, for Peppler, is a “powerful constructionist idea,” lying at the heart of design for creativity. She therefore calls for a closer examination of ideas coming directly as solutions to open problems.

« 4 » Both perspectives on powerful ideas take our initial theoretical views developed within the realms of this research one step further. We agree with Peppler that sustainability is a powerful idea in itself. Added to its societal importance, complexity, systemic nature and boundary character, which ground its power from a constructionist perspective, we would also like to note its inherent “plasticity” and its “heuristic relativistic” character (Megill 1995), which assign a genuine creative potential to the construct of sustainability and turn it into a fruitful arena for creative learning activity (Daskolia & Kynigos 2012). This is because it makes learners become aware of the limits of their individual standpoints and urges them to stand off and explore others’ or alternative perspectives as complementary frames for better grasping their surrounding world. Finally, we would like to add one basic finding from creativity research literature: sustainability is an idea that allows crossing different idea spaces, with different assumptions and goals. This act of crossing gradually builds a web of information, in which creative ideas flourish (Ogle 2007).

« 5 » But is that all? Is it just the aforementioned characteristics of sustainability that afford creative and constructionist tinkering around the concept? Can we think of it as an “idea generator,” a pool with a no-ceiling potential for other creative ideas? And do the latter have to be reified in digital artefacts in order to be creative? Or is their articulation just enough to make them “creative”? These are some insightful questions that were born out of the discussion initiated over whether and how sustainability is a powerful idea.

« 6 » On the other hand, Peppler’s focus on ideation in relation to problem analysis allows us to make a connection to the “specificity versus abstraction” debate (Ward, Patterson & Sifonis 2004: 2) and to a basic finding in the literature on problem formulation: that more abstract problem formulations do seem to allow more originality than, for example, specific exemplars. In our research, the construct of urban sustainability and its multiple facets gave way, from a very early point, to abstraction. In one of the stories produced, the group decided to use the technique of symbolism, coming out of ideas directly as solutions to open problems.

« 7 » A second point by Peppler we would like to build upon is the extrapolation of systems and causal thinking in storytelling. Quoting Linda Booth Sweeny (2012): “When we ask students to move beyond simple, linear explanations of causes, we are asking them to be literate about systems.” Giuliana Dottori’s line of argument, in her finely tuned theoretical grounding of narra-
Educational Research Concepts in Constructionism

...also points towards a systemic view of narrative, seeing stories as “meshes of interrelated ideas [...] thus helping to overcome the intrinsically linear nature of human discourse and combining richness of content with simplicity of form” (82). What happens, though, when stories become digital? What is the impact of the medium/tool used in the structure and content of the narrative? Can specific technical affordances induce, or even constrain systemic thinking, and to what extent? Peppler’s ($4$) proposal for using non-linear and interactive media to support thinking about sustainability in a systemic way is a way forward to exploring alternative technologies based on hypertext (for example, interactive timelines, blogs or other Web 2.0 applications).

« & » A final, very insightful point is made by Dettori ($6$) on an issue scarcely explored in educational contexts: feelings and affective aspects. Affective learning and its various nuances have been gaining momentum in the field of educational technology over the past few years. In their “manifesto on affective learning,” Rosalind Picard et al. (2004) sketch a vision of how constructionism can support important aspects of the affective domain: at its core, their argumentation is a constructionist frame to learning about sustainability in a systemic way is a way forward to exploring alternative technologies based on hypertext (for example, interactive timelines, blogs or other Web 2.0 applications).

Combined References


Amusement, Delight, and Whimsy
Humor Has Its Reasons that Reason Cannot Ignore

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> Context • The idea for this article sprang from a desire to revive a conversation with the late Ernst von Glasersfeld on the heuristic function – and epistemological status – of forms of ideations that resist linguistic or empirical scrutiny. A close look into the uses of humor seemed a thread worth pursuing, albeit tenuous, to further explore some of the controversies surrounding the evocative power of the imaginal and other oblique forms of knowing characteristic of creative individuals. > Problem • People generally respond to humor, i.e., they are inclined to smile at things they find funny. People like to crack jokes, make puns, and, starting at age two, human infants engage in pretense or fantasy play. Research on creativity, on the other hand, has mostly scorned the trickster within. Cognitiveists in particular are quick to relegate wit, whimsy, and even playfulness to the ranks of artful or poetic frivolities. > Method • We use the emblems of the craftsman, the trickster, and the poet to highlight some of the oblique ways of knowing by which creative thinkers bring forth new insights. Each epitomizes dimensions intrinsic to the art of “possibilizing.” Taken together, they help us better understand what it means to be playful beyond curious, rigorous beyond reasonable, and why this should matter, even to constructivists! > Results • The musings characteristic of creative individuals (artists, scientists, children) speak to intelligent beings’ ability to use glitches intentionally or serendipitously as a means to open up possibilities; to hold on to a thought before spelling it out; and to resist treating words or images as conventional and arbitrary signs regardless of their evocative power. To fall into nominalism, Bachelard insisted, is a poet’s nightmare! > Implications • Psychic is image, said Jung, and when we feel alive we rely on the imaginal to guide our reason. Note that image is not here to be understood as a picture in the head or a photographic snapshot of the world. The imaginal does not represent, it brings forth what we understand beyond words. It does not lock us into a single mode. Instead, it is a call to be mindful, in Ellen Langer’s sense: in the present, mentally alert, and on the outlook for our psyche’s own surprising wisdom (sagacity). > Constructivist content • Debates on the heuristic function and epistemological status of oblique ways of knowing have long occupied constructivist scholars. I can only guess whether my uses of Jung’s imaginal or Bachelard’s anti-nominalism would have amused or exasperated Ernst! I do know that, on occasion, Ernst the connoisseur, bricoleur, and translator allowed the rationalist-within to include the poet’s power to evoke as a legitimate form of rationality. He himself has written about oblique knowing as legit! > Key words • incongruity, playfulness, mindfulness, trickster, craftsman, poet, glitches.

Introduction

The most common kind of joke is that in which we expect one thing and another is said; here our own disappointed expectation makes us laugh.

(Cicero, On the Orator)

Like play itself, humour is hard to define, and its role in creative thinking remains to this day under-explored. The most widespread, and still controversial view among researchers is that the sense of levity that arises from appreciating humour is a response to the perception of incongruities. James Beattie was among the first to point out that humorous laughter (our smiling at something funny) occurs when…

In a similar way, Immanuel Kant (a contemporary of Beattie) saw laughter as an affection that sprang from the sudden transformation of a strained expectation into nothing. To Kant, however, this transformation is of no use to understanding. In his words:

A joke amuses by evoking, shifting, and dissipating our thoughts, but we do not learn anything through these mental gymnastics. In humour, our reason finds nothing of worth, even if the jostling of ideas produces a physical jostling of our internal organs and we enjoy that physical stimulation** (Kant 1911: Part I, Sec. II: 54)

Such un-impressed views on the potential of whimsy can be traced back to early Greek philosophers. Plato, in particular, saw laughter as an emotion that overrides human rationality and hampers self-control. And Aristotle, who recognized the virtues of wit in everyday conversations, still portrayed humour as a form of educated insolence, i.e., the clever expression of underlying scorn. In Nicomachean Ethics (Book IV, Chapter 8), he warns that most people

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enjoy amusement and jesting more than they should (Aristotle 1941).

« 3 » A different and more generous take on humour can be found in Arthur Koestler’s definition of humorous laughter as...

**a luxury reflex, which could arise only in a creature whose reason has gained a degree of autonomy from the urge of emotion, and enables him to perceive his own emotions as redundant – to realise that he has been fooled.** (Koestler 1964: 96)

In The Act of Creation, Koestler treats humour and creativity on an equal footing, and defines both as highly evolved forms of human expression, none of which can be understood in terms of reason or instinct alone. Instead, according to Koestler, all require “the perceiving of a situation or idea… in [at least] two self-consistent but habitually incompatible frames of reference.” Koestler uses “bisociation” to describe the act of shifting between – and bringing together in novel ways – different “matrices of thought.” He offers countless examples of the senses of surprise (awe, amusement) and quid pro quo (double-entendre) that arise from the juxtaposition of otherwise unlikely “orders of things.” Important in Koestler’s perspective is his emphasis on the role of artful displacement, playful exaggeration, and suspension of disbelief in human creativity – and understanding – whether humorous, scientific, or artistic.

Wit and whimsy: Homage to humour

« 4 » Wit is best defined as the keen perception and cleverly apt expression of surprising juxtapositions between unlikely occurrences in ways that bring about amusement. And whimsy points to a quaint, fanciful, and mostly gentle form of humour that arises from treating “glitches,” or quirks, as serendipitous “overtures” to unexpected possibilities. Both wit and whimsy call for a playful attitude: an attitude that, for no apparent reason, allows itself to change its mind (in a whim), to leap, and to shift gears! To this day, the “trickster within” is seen as a potentially destructive force. Yet the lightness of being and sense of delight associated with our abilities to produce and enjoy humour are at the heart and core of the insight-led explorations characteristic of creative individuals.

« 5 » In my talk “On mindful learning, Art challenges habits and certitudes,” I argued that our rational minds’ urge to predict, explain, and validate currently held beliefs (make sure we are right) is important. Yet, it is in no way sufficient – and different – from a creative person’s uses of the unexpected as a lever to engender new ways of thinking (envison alternatives). Both require curiosity, engagement, and skills. Both are about bringing forth otherwise hidden “truths.” And both emerge from a desire to venture off the beaten path and to see what is on the other side of the fence. Yet, the manner of defining and monitoring progress, the criteria of rigor and success, and the uses of and tolerance to the unexpected are different.

« 6 » In what follows, I discuss how creative individuals (children, scientists, and artists) make sense of their experience, envision alternatives in their minds, and bring forth novel insights, in ways that can move beyond proving and evoke beyond explaining. Being mindfully engaged, adopting a beginner’s mind, and letting our minds wander and wonder are some of the ways in which intelligent beings come to know more about what they do not know yet and – equally important – come to question what they know!

Mindfulness and playfulness: A beginner’s mindset

In the beginner’s mind there are many possibilities, in the expert’s mind there are few. (Shunryu Suzuki, Zen Mind, Beginner’s Mind)

« 7 » Mindfulness, to Ellen Langer, is about putting our mind into what we are doing at the moment we are doing it (Langer 1989) and, in this sense, is akin to Mihaly Csikszentmihalyi’s (1990) notion of “flow.” Mindlessness, in contrast, emerges as a result of having it all figured out. Experts, to Langer, are especially prone to becoming mindless whenever they put themselves on autopilot and cease to look at what they know as a potential obstacle in disguise: whenever they rely heavily on acquired skills, or apply standard routines. Being playful, on the other hand, is about suspension of disbelief as a means to coming to see anew, which in turn requires that we adopt a beginner’s mindset. Mindfulness and playfulness are both integral to human creativity. Their combined role is to keep us alert, in it for surprises, and willing to look at things twice and, each time, as if for the first time!

Mindless, mindful: When knowing gets in the way

« 8 » According to Langer, mindlessness is easier to define than mindfulness! At the core of the idea of mindlessness lies the paradox: the more we know the more likely we are to act mindlessly. Langer mentions three potential sources of mindlessness:

• categorizing thinking;
• acting or thinking from a single perspective; and
• habituation.

« 9 » Each comes with its pros and cons. Categorical thinking, i.e., defining, ordering, and clustering things (putting them in pre-established boxes) is vital for operating effectively in the world. Yet imposing our order also puts us at risk of ignoring anything that does not fit our expectations. We become extreme assimilators, unable to see, let alone incorporate, odds. Likewise, thinking from a single perspective, or going down a set path, satisfies the “cognitive miser” within. Yet following a set path without budging, even when no perceived benefits arise, locks us in. Lastly, once our ways of doing and thinking become second nature, we may gain fluency, yet unquestioned habits also get in the way as soon as the conditions change.

« 10 » Being mindful, in contrast, is defined by Langer as a continual and very active quest for novelty, and novelty is not to be seen here as a need for increased external stimuli! As Langer points out, you can read a book many times and bring to it something new each time. It is, in other words,
our vested interest, and not the stimuli, that makes for an experience worth having. Unlike Langer, I do not define mindfulness as a quest for novelty per se, but as a readiness to bring whatever intriguces us to a next step and to see where it may take us. Children, in this sense, are always mindful, even as they play, alas especially as they play! Always in the moment, curious, and delighted when things are not as they appear, they revisit what captivates them a hundred times, introducing slight variations each time, and thus bound to notice something new along the way. Think of a toddler learning to walk. She pulls herself up, takes a few steps, and plops down. With a determined look on her face, she then gets up again, and down, and up. Adults for their part, are much more deliberate in how they draw a line (or switch gears) between the cognitive miser (sparing, in search of closure, consistency, solutions) and the flaneur, (sentient, in search of breaches, surprises, overtures). Both are connoisseurs. Both are inquisitive. Yet the first is drilling (industrious) while the second is leaping (playful).

Play as a way of knowing: As if for the first time

“A beginner’s mind, we have seen, rids itself from the “been there, done that” attitude: a reminder that whenever we have got it all figured out, or think we do, chances are, we do not pay much attention. We will get frustrated because we expect one thing and it does not happen that way. Adopting a beginner’s minds is akin to a child taking the long way around (“le chemin des écoliers” in French), with the tacit or explicit understanding that if you wander off, take your time, and keep looking, you are likely to meet the unexpected in ways that, in turn, can be exciting, wonderful, and call for more. Adopting a beginner’s mind is not about falling back into childhood literally. Nor is it a way of denying a mature person’s experience or expertise. Instead, it requires that we (1) keep asking (avoid the and-then attitude); (2) tolerate uncertainty (hold on to what puzzles us before rushing to solutions); and (3) shift perspective, or re-position ourselves, to look at things afresh, as if for the first time. All three, I posit, are ways of coming to know, in their own right!

Mindful and playful: What has it to do with learning and cognitive development?

“Being playful involves the safe exploration of otherwise risky ideas through suspension of disbelief. Its motto comes in two parts: make it up (do as if) to try it out (do!) and revisit (re-enact) it and build on it (re-create) to learn from it. Early on, children engage in pretend or fantasy play, fusing and decoupling their action by shifting constraints and possibilities. Holding to—and exploring—this tension between what is and what could be, through imaginary projection and symbolic recreation, shields the playing child from potentially harmful consequences. It also lays at the core of what it means to be intelligent, in Piaget’s (1951) sense (Ackermann 2004). When we play, we feel alive and keenly interested in what we’re doing (Winnicott 1971). One implication of this is that a person can be curious and not very playful. At the risk of caricature, let me suggest that beyond asking “why” and seeking closure, playful spirits keep asking “what if” and use their own wanderlust as a lever to come to reason (get to know more). They turn the familiar into the extraordinary instead of looking at the unknown as a kind of familiar.

The ways of the craftsman: Caring for things well done

Craftsmanship is an enduring, basic human impulse, the desire to do a job well for its own sake. (Richard Sennett, The Craftsman)

“Through mindful immersion, the craftsman establishes a deep connection between head, eyes, hands, and tool (or machine). And as he perfects his art, the materials at hand are made to talk back through their resistances, ambiguities, and by the ways they change as circumstances change. An enlightened craftsman enjoys such a dialogue and, in doing, develops an "intelligent hand" and a "perceiving mind": he becomes one with the materials. Richard Sennett groups craftsmen into three types: Homo Faber, Homo Laborans, and Homo Ludens. Homo faber (maker) is the creator and judge of material labor and practice. Homo laborans (worker) takes the task at hand as an end in itself. Homo ludens (player) is absorbed in pursuing for the sheer pleasure of it. All require a desire to perfect and the skills to deliver. Yet the techniques of the craftsman are anything but a mindless application of pre-written rules. Sennett writes:

“Every good craftsman conducts a dialogue between concrete practices and thinking; this dialogue evolves into sustaining habits, and these habits establish a rhythm between problem-solv-
ing and problem-finding. There is nothing inevitable about being skilled, just as there is nothing mindlessly mechanical about technique itself. (Sennett 2008: 9)

Architect Renzo Piano has this to add about repetition and practice:

"You think and you do at the same time. You draw and you make. Drawing is revisited. You do it, you redo it, and you redo it again. That's where the pleasure lays." (Sennett 2008: 40)

**Trickster, jester, clown: A hymn to the creatures of mischief**

Feste is described as “a man wise enough to be simple.” He is oblique with interpreting Trickster anew. Every generation occupies itself with interpreting Trickster anew. (Paul Rodin, The Trickster)

"The disruptive side of our human intelligence is epitomized by the figure of the joker (trickster, jester, clown). Emblematic of creative and cultural renewal, the trickster fascinates for how he transgresses boundaries. The jester is a licensed fool employed by monarchs to amuse the court and dispense hard truths. And the clown is meant to be funny, can be awkward. Masks are sometimes scary, as can be poker faces. You do not know what hides behind!

"Clowns mostly employ slapstick or similar types of physical humour in a mime style. They appear in outlandish costumes, and wear make-up, red noses, colourful wigs, and oversized shoes. From Pierrot to Harlequins, their act may vary. Clowns can be feared (by children and adults) if they appear outside their “natural” circus environment. Their appearance, meant to be funny, can be awkward. Masks are sometimes scary, as can be poker faces.

"What we distrust in fantasizing and imagining is the revelation of the uncontrollable aspects of our psyche. The removal of ‘fixation’ is possible through playful – and sometimes painful – displacement, characteristic of the trickster: now this and now that; now here and now there; peek-a-boo. A trickster pulls your leg, not as in deceiving but as in pretending, exaggerating, stirring.

"Tricksters by excellence, tricksters are out to satisfy their inordinate appetites. At the edge, in between, and over-the-top, they make it their job to cross the line and blur distinctions. The trickster is a figure of mischief. Like circus people, he belongs to the periphery, and will not use his power for the sake of conformity. His view is oblique because he does not belong. The trickster is a wanderer at heart.

"Jesters

"In Shakespeare’s Twelfth Night, Feste is described as “a man wise enough to play the fool.” Jesters were hired their wit and their role was to entertain and amuse the court (play music, juggle, tell riddles, sing, dance). Taking advantage of the license to mock, these highly skilled itinerant performers (dressed as fools) enjoyed the privilege to dispense frank observations and highlight the follies of those who ridiculed them. Only as the lowest member of the court could the jester be a monarch’s trusted adviser.

"What is the revelation of the uncontrollable aspects of our psyche. The removal of ‘fixation’ is possible through playful – and sometimes painful – displacement, characteristic of the trickster: now this and now that; now here and now there; peek-a-boo. A trickster pulls your leg, not as in deceiving but as in pretending, exaggerating, stirring.

"Jokers" as strangers

"The stranger, notes Georg Simmel, learns the art of adaptation more searching, if not more painfully than people who feel entitled because they belong to a community of settlers who know, and own, their surroundings. In Simmel’s view, the foreigner holds up a mirror to the society into which she enters, for as a foreigner he cannot take for granted ways of life that seem so natural to natives. Humans are skilled makers of a place for themselves. Yet only a sense of self-displacement and estrangement, characteristic of both creative people and travellers, can drive the practices of change and open the way to cultural renewal (Simmel 1964).

**Of poets and muses: Insightful to enlivened**

Every man is a poet when he is in love. (Plato, Symposium)

"More than the craftsman, and maybe better than the jester, the poet seeks inspiration through the inner voices of whom he is a mouthpiece! When the poet uses words, the words sing and dance, when she uses images, they reverberate. In “Mythologization of Reality,” Bruno Schultz writes of the poet, “In [his or her] hands the word comes to its senses about its essential meanings, it flourishes and develops spontaneously in keeping with its own laws, and regains its integrity” (Schulz 1993: 49–50). What makes the poet different from the rationalist or discursive thinker is that she lets her creations “speak” for themselves. A good example is music. Art, like myth, is made to touch, move, and stir (to inspire) and not merely geared toward teasing things apart for the purpose of explanation. The poet’s power comes from a reluctance to nail down, or explain away, the fleeting insights that “transport” him for fear of taming his flame. And that is precisely why, if successful, the poet captures our imagination.

The Imaginal: Staying with the Image

"Psyche is image, said Carl Jung, and when we feel alive we rely on the imaginal to guide our reason. Note that image is not to be understood here as a picture in the head, or a photographic snapshot of the world. The imaginal does not represent, it brings forth. What’s more, in Jungian parlance, sticking to the image does not imply that we get locked into a single vision or mode of envisioning. It is not about being mesmerized. Instead, it calls on our abilities
to see the bear in the bush, the bush as a bear, and the light through the bush (see things in more than one way) and continually look out for – stay in touch with – the psyche’s own capricious nature and untamed sagacity! To Jung, the psyche is “real” to the extent that it constantly opens up new possibilities and provides new insights. The psyche uses fiction and fantasy to find its ways and the images engendered are exactly as they appear; illuminating as long as they last, never standing still, indefinite except through their interweaving. The sensual qualities of an image (form, colour, texture) are not copied from objects and they never replace reality, as is the case in visions or hallucinations. Instead, the “truths” of the imaginal is to give form to guiding fictions whose function is to capture the ineffable, multiple, polymorphic quality, as is the case in visions or hallucinations.

See ing and doing: Imagine to create

“25” For Ernst Cassirer, as for Goethe, there is creation in the very act of seeing. Cassirer (1944) uses “productive imagination” to describe the unconscious ideation that accompanies any act of perception. The distinctive feature of artistic imagination is that it further abolishes the opposition between content (the latent) and form (the manifest). For Cassirer, art, like myth, is not representational or discursive in nature. It performs. Echoing Cassirer and Goethe, Gaston Bachelard warns against the temptation to view images and words as signs, and then claim that any well-formed strings of signs can echo what they stand for. In Poetics of Space (1994), he posits that, unlike signs, symbols are lived, experienced, re-imagined in an act of consciousness, which restores at once their timelessness and their newness. To fall into nominalism, he insists, is a poet’s nightmare. It eclipses the power of words and proceeds to their systematic sterilization by tearing them apart from the substrate in which they reside. Along with Bachelard, I doubt that any artist, scientist, or philosopher could move or touch us if the expression of their views were not allowed to breed their own life. There is no knowledge without imagination, no imagination without playfulness, or suspension of disbelief, and no creative act without bringing our fantasies (visions) to life, and then back into the world.

Craftsman, trickster, poet in the arts, science, and human creativity

“26” All branches of human experience – science / philosophy / arts / mythologies – are invested in a quest for “truths.” And in their mature form, each offers their own unique windows into the workings of the human mind – as well as the (hu)man-made world in which we live. The views also vary in significant ways. Reuniting the artist and the scientist “within” would be the equivalent of reinventing a Renaissance man, which may not be easy, or desirable, because it would require a hard-to-strike balance along a continuum of opposites, which rarely reside within a single mind (Table 1). “27” Let me elaborate. To the poet, we have seen, the power of the word (or image) resides in the fact that it tenses and strains to produce a thousand associations. And what the poet warns us against is the senseless use of conventional and arbitrary signs or symbols for the mere purpose of explaining things away or proving a point. Said otherwise,

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<tr>
<th>The artist’s ways – in search of meaning</th>
<th>The critic’s ways – an urge for certainty</th>
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<td>delights, amuses</td>
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Table 1 • The artist and the critic. The main differences between the columns are: 1. the evocative vs. literal uses of symbols or signs; 2. the importance attributed to insight (i.e., seeing anew) vs. proof (i.e., validation) in the quest for understanding; and 3. the different exploratory (“what if”- vs. “if then”- driven) as well as expository styles (show vs. tell; reveal vs. explain).

As we manipulate everyday words, we [should not] forget that they are fragments of ancient stories, that we are building our houses with broken pieces of sculptures and ruined statues of gold as the barbarians did. “28” (Schulz 1993: 88)

The scientist on the other hand, relies on language to calculate (run operations) and she cringes if the meanings assigned to words remain “sticky” (fused, onomatopoeic), if descriptions are “thick” (polysemic), let alone if the rules start shifting! The rationalist is not in it to gain insights or understanding through mindful engagement or playful displacements. Instead, he uses the language of reason (logic) as a means to leverage and validate knowledge, thus favouring order, stability, and closure over serendipity, variability, and uncertainty.

“28” In conclusion, while useful to build an argument, justify a statement, or calculate, rationalism sometimes ignores the knowledge-inducing messiness of the scientific enterprise itself. It can be an art too, and art itself is a way of knowing.
Learning from children

What is to be learned from children is that, not unlike like “Renaissance men” yet for different reasons, they too assign roles to their voices within, through a masterful, and trickster-like, tour de force. Let me put it this way: because they “do not know better,” children unknowingly let the poet reason, the jester rule (as in “let’s say I’m a wolf”), and the craftsman dream! The adaptive advantage of such early indifference is that they allow the growing child to err without getting lost, and to pursue the journey without needing to know its destination in advance.That is, in addition to holding onto their own “theories” (imposing their order), children are “shape grammarians” in George Stiny’s (2006) sense. They let their senses guide and their minds meander. And this in turn allows them to move swiftly between realms (here-now, then-there) and to come to see things anew, or obliquely, as if for the first time, through playful re-enactments (revisit, recast) and suspension of disbelief (do as if).

Most striking in this respect is children’s natural tendency to invert the very levers, supports, and metaphorics they need to navigate a world by definition beyond mastery. Their extraordinary gift as self-directed learners comes in great part from their ability to let their minds wander, and wonder, while at the same time, making sure of their ground (building the security nets that allow them to venture safely into uncharted territory). Doing as if and playing what if are some of the techniques used to achieve this balance. We also know from research on pretence and fantasy play (cf. my talk “On mindful learning”) that a child’s ability to engage in make-believe acts requires a decoupling not unlike the bisociation Koestler alluded to regarding humour. And indeed, if we see a three-year-old hopping across a room using a broom “as if” it were a horse we – as well as she – know very well that the broom is not “really” a horse. Yet she rides it, undisturbed and amused! Likewise, a child who bosses around her imaginary companion or drinks out of empty cups is neither delusional nor is she confused. She is just playing; and playing – like humour – opens a means to see things in a different light. Without decoupling, or bisociation, no digression would be conceivable, no ambiguity or uncertainty embraced, and no surprise enjoyed. As humans, we would not only lack a sense of humour but miss out on the opportunity to grant ourselves the mental “elbow room” needed to free the cognitive miser from digging itself into a hole. It takes a trickster to let the genie out and make us see afresh.

Lessons for learning and the practice of design

The insight-led musings characteristic of creative individuals are particularly relevant in design, where the creation of new forms (sketches, models, representations) cannot be at the image of what’s out there – since not much is out there yet! Thus designers, like craftsmen, are left with evolving their drafts as they go! What is true of design is also true of other constructive processes. To design (proiettare in Italian) is an iterative process of mindful concretization, or materialization, of ideas (concrétaison réfléchite in French). Ideation, on the other hand, is more akin to what Jean Piaget called “abstraction refléchissante,” i.e., our abilities to internalise actions, hold on to our views, and to anticipate as well as draw conclusions in our head. Both are at play as we seek to get a handle on “ill-defined” problems, and both involve trial-and-error, re-visitations, and refinements along the way. Yet, reconceiling the tinkerer and the thinker within cannot ensure that we progress creatively, or imaginatively. What is needed, in addition, is a willingness and ability to step sideways, antennas out, and in it for surprises. In other words, beyond planning ahead and sticking to the plan (unless irrevocably cornered) or erring blindly, the playful wanderer progresses through his own wondrous musings. Along with my mentor Piaget, I think that projecting meaning onto the objects of our experience (by “assimilating” what we see to what we know) is a pillar of cognitive adaptation. In contrast to Piaget, I like to put greater emphasis on the accommodative pole of adaptation (giving in to the odds as a means to question the obvious). And this does not come without complications within a constructivist framework! At the cost of caricaturing, let me put it this way: fellow constructivists sometimes seem to ignore that, once launched, a human artefact takes on a life of its own, thus transcending both the author’s intentions and any singular act of interpretation.
Conclusion

Most of us would like to believe that when we say something is right or wrong, we are using our powers of reason alone. (Carl Zimmer, Whose Life Would You Save?)

« 32 » As mentioned in the abstract, the idea for this article sprang from a desire to pursue a longstanding conversation with the late Ernst von Glasersfeld on the epistemological status of oblique forms of ideation, which resist linguistic or empirical scrutiny. I have shown, in the article, that the uses of humor and other forms of artful détourne-ments and bisociations allow intelligent beings to expand their experience “knowingly” in ways that reason alone cannot achieve, or rationally account for! Cognitive misers, we have seen, tend to take things at face value and reason their ways out of questions in order to seek closure. Playful individuals, on the other hand, do not hesitate to dramatize in order to “de-dramatize” (get at the core of things), and resort to metaphors as a means to sharpen their understanding. Ernst the rationalist delighted in relegating both poets and artists to the ranks of the mystics (Ackermann 2013). Mysticism, to him, may well be another form of knowing, but it cannot be formulated within a rational frame-work, and thus is of no interest to the radical constructivist. End of conversation!

« 33 » Unsurprisingly, Ernst the conversationalist was also, on occasion, open to questioning the hard-liner within. And that is when, one beautiful day, he pulled out of his hat a paper entitled “Metaphors as oblique descriptions.” On page 5 he wrote:

« 34 » In “The incommensurability of scientific and poetic knowledge,” Ernst further stated:

« 35 » So, in the end, if scientists and mystics are both needed to ensure our survival, why not just treat any theory as a heuristic fiction? Conversely, if our conceptions rest upon a history of “creative” shifts and quirks, why not close the gap between rationality and sagacity, logic and insights. As mentioned earlier, glossing over the messi-ness underlying our coming to reason, as intelligent living beings, seems to be the antithesis of what constructivism itself is about.

Acknowledgements

I wish to thank Gerald Futschek and Chronis Kynigos, the organizers of the Constructionism 2014 Conference in Vienna, for their dedication and work.

Received: 23 February 2015
Accepted: 20 April 2015
All Alone, Together?

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> Upshot • My commentary on this target article departs from the final part dealing with “Ernst-the-rationalist” and attempts to draw out a series of complications in the ways we may understand Ernst von Glasersfeld’s radical constructivism. Special attention is given to the presence of incommensurability and incompatibility, not only between people but more so within any given individual.

1 « Edith Ackermann’s final description of “Ernst-the-rationalist” describes the limiting conditions of radical constructivism in relation to our rational claims to knowledge. These limiting conditions imply that poets, artists, visionaries, oracles and the like are bundled together as mystics, whose alternative modes of coming-to-know cannot be formulated in ways that might allow them to make claims about rationally knowing anything. Here, there is an unbridgeable gap between the rational-theoretic disquisition on, for example, a work of art and, on the other hand, the deeply subjective experiencing that I may undergo of the art object in question. My experience remains rationally inexplicable.

2 « However, the problems that arise for our radical constructivist understanding of ourselves as “human” go way beyond the technical problem of claiming rational knowledge in a scientific community. The limits on such “claims to knowing” derive from the radical constructivist position that we cannot share our experience. This same position on human experience furthermore implies that we cannot “understand the other person” nor can we “be understood” by them (Kenny 2015: 243).

3 « Our “mammalian brain,” which is busy with the coordinations of emotions in a network of affectivity with others, becomes the locus of the illusion that we are “sharing experiences.” This coordination of emotions generates the illusion that we are “sharing emotions,” especially where the emotions are intensely felt by the participants and it is visible to any observer as to which emotions they are experiencing individually. So people who attend a funeral (with the strong emotions of grief) or who attend a film comedy (with strong emotions of laughter) or who are present with a patient when their doctor gives them the bad news about their health prospects (with strong emotions of fear of death) can all enter into the illusion that they are “experiencing the same thing.” It is easy to take this false step to believing that these persons are experiencing the “same emotions.” Under such circumstances, people feel “closer” to one another and believe that they “feel the same.” But this assumption is erroneous in that they are never in a position to know exactly what the experience of the other person actually is.

4 « The illusion of “sharing experience” facilitates us as mammals to “stick together,” recognizing a common identity in “being human” by manifesting similar signs and symptoms of what is “essentially” a private emotional experience. Revisiting Ludwig Wittgenstein’s speculations on the possibility of a private language, we read that he says:

5 « The idea of a “private language” arises where the words of such a language can refer only to what can be known to the speaker themselves (their sensations, experience, etc.) and so are not “knowable” or comprehensible to another person. Experience must always be construed if we are to think or say anything about it, even to ourselves. In the absence of some effort at construction, our experience remains unnoticed in the domain of preverbal events. As Humberto Maturana (1988b) often says, we live in two non-intersecting domains, in the domain of experiencing and in the domain of explanations.

6 « I would say that because we do not have any privileged access to our own experience, it then follows that this form of inaccessibility renders the experience a precisely “private language” that not even we ourselves are able to “decodify.” This means that our own experience remains “private,” even from ourselves.

7 « A different way to say all this is to refer to Gregory Bateson’s notion (1991a) of the “contingencies of relationship.” That is, that the non-verbal signs that we take to signify an “inner state” are more importantly understood in terms of the function of such signals in an interpersonal network of role relationships, and their implications for how their interactional contexts are managed.

8 « When the “illusion of sharing” comes unstuck, people run into difficulty and begin to elaborate “solutions” in relation to the threat of the loss of this illusion. In therapy, two of the most extreme manifestations are presented by, on the one hand, the person who is mistakenly seeking a pro-
foundly symbiotic relationship ("merging" solves the "sharing" dilemma – "losing oneself" in another) and, on the other hand, by the person who gets labelled "schizophrenic" (taking the impossibility of "sharing" to the extreme of a "schism" of the distinction of an internal vs. external reality – "losing oneself in oneself") and ceases to engage in the meta-communication (Bateson 1991b: 130) necessary to coordinate activities with others.

Incommensurability and incompatibility

While for von Glasersfeld the different modes ("rational" vs. "mystic") of coming-to-know were incommensurable, they were not necessarily incompatible. However, it is clear that if we take any given individual, who may from time to time adopt a rational mode of coming-to-know or a non-rational mode (poetics, art, creativity, etc.), then it is likely that in their resultant wide-ranging experiences, they themselves will find (if they are incautious enough) various forms of incommensurability within their alternative experiential modes of coming-to-know.

George Kelly elaborated this as part of his fragmentation corollary, which states that "A person may successively employ a variety of construction subsystems which are inherently incompatible with each other" (Kelly 1955: 83). Kelly wanted to include in his theory explicitly the fact that people have a habit of "contradicting" themselves from one time to another by using successive constructions that are not derivable one from the other, as when we have a novel idea that is new exactly because it is not a direct derivative of our old constructions. This is a corollary that prompts us to seek out the over-riding regnant construct structures and the order of the contextualizing construct system organization within which local incompatibilities may make sense. Kelly puts it like this:

**If one is to understand the course of the stream of consciousness, he must do more than chart its headwaters; he must know the terrain through which it runs and the volume of the flood which may cut out new channels or erode old ones.** (Ibid)

So here again, we have an appeal to pay attention to the complexity of the contextualizing system, together with an appreciation and comprehension of its intrinsic incommensurabilities and incompatibilities. These gaps of incommensurability may be found at all the "steps" or "transitions" in the processes of "coming-to-say" something that is worth "saying" to another person. The fact that one "feels" that there is something that one has "come-to-know," and that it is "worthwhile" communicating to someone else, is obviously preceded by an experience of "talking to oneself" across a series of "gaps" (an unexamined process that we take absolutely for granted), which include:

- the initial sensations that there is something I want to say;
- trying to focus my conscious attention on those "sensations-about-to-become-ideas," before the still-emerging notions become graspable (as a pre-verbal "image-idea");
- attempting to tell myself (by selecting certain words which promise to "hold" and "express" to myself) what the originating preverbal sensation-of-knowing was;
- tightening my word-label grip on the "semantic handle," which I try to affix to the "true sensations" (insight, new idea, etc);
- choosing how to say these words so that my listener might also "grasp the idea" – which is "essentially" a preverbal sensation or conviction.

It would be better to describe this process as "talking (and taking) one's self across a series of yawning gaps," rather than it being merely "a talking to oneself."

In all of this process of communication there is a series of "parallactic gaps" (Žižek 2006: 4–7), and at each "gap" there is the dilemma of incommensurability. So, on the "inside" of our experiential world we find the same problems of incommensurability as we find on the "outside." In the domain of communication, in the "outside world," where scientists find themselves unable to make agreements because their theories are embedded in variously contrasting conceptual frameworks whose languages speak "past" one another and which lack a sufficient degree of "overlap" to permit the emergence of some workable compatibilities (Feyerabend 1962).

Kelly tells us that we are in the habit of using alternative constructions that are inherently incompatible among themselves. So here the situation becomes more complex in that we have (i) clear degrees of incommensurability and also (ii) degrees of internal incompatibility as the normal state of one's personal construct system. For this reason Kelly encouraged us to embrace antinativism ("as-if-ism") as a way of living and to avoid getting "bogged down" in our limitations of language structure and usage. In trying to warn us about the dangers of finding that the masks we wear end up sticking to our faces, and, in a parallel process, how the verbs we use to invite ourselves to experiment with experience tend to lose their powers to instigate novel experience, Kelly observes that:

A student who is awarded a Ph.D. degree can find a lot of adventure in being called 'doctor' and the academic mask may enable him to experiment with his life in ways that would have seemed much too preposterous before his dissertation was accepted. But trouble sets in when he begins to think that he really is a doctor, or a professor, or a scholar. When that happens he will have to spend most of his time making noises like doctors, professors, or scholars, with the resultant failure from that time on to undertake anything interesting. He becomes trapped by verbs that have lapsed into the indicative mood when he wasn't looking. **(Kelly 1969: 159)**

Kelly noted the importance of trying to maintain a conjectural pose as often as possible, to be aware of and to extricate ourselves from seeming to be trapped into an apparently implacable objectivity, created by our own use of the language of realism. Kelly notes:

Nowhere is this semantic enslavement clearer than in the psychotherapy room. It is there one can see most clearly how man can be trapped by his indicative verbs and how, in turn, he has been led to believe that he must choose between mutually exclusive versions of reality. **(1969: 162)**
Philosophical-Psychological Concepts in Constructionism

Žižek observes, quoting Kojin Karatani: “experiencing, precisely because they put us apparently incompatible domains of human experiences, so that there are more opportunities to co-construct fellow travellers – but without cultivating the illusion of ‘sharing experience.’”

I believe that the relevance of the area of whimsy, humour, amusement and play offers a good opportunity for creating some initial basis of the work of bridging apparently incompatible domains of human experiencing, precisely because they put us in front of these parallactic gaps. As Slavoj Žižek observes, quoting Kojin Karatani:

“Kant’s stance is thus to see things neither from his own viewpoint, nor from the viewpoint of others, but to face the reality that is exposed through difference (paral- lax).”

and he continues,

“the Kantian ‘transcendental’ stands, rather, for their irreducible gap ‘as such’: the ‘transcendental’ points to something in this gap, a new dimension which cannot be reduced to either of the two positive terms between which the gap is gaping.”

Vincent Kenny is the Director of the Accademia Costruttivista di Terapia Sistemica in Rome. Current activities involve applying psychology and philosophy to three areas where people find themselves in difficulties: (a) interpersonal difficulties with others (known as “psychotherapy”); (b) conflicts in organisational communications in networks of conversations (known as “organisational consulting”); and (c) problems of professional tennis players who run into difficulties of self-interruption in the international tennis tournaments of the ATP/WTA circuits around the world (known as “tennis psychology”).

Towards a Delightful Critique of Pure Reason
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>Upshot • Ackermann’s target article strikes a chord by thinking together oblique and rational aspects of knowing, Her target article points out uses of humor and various ways of making sense of our experience that have been underemphasized in constructivist discourse. While I can agree on the main lines of her argument, I want to argue for further differentiation and clarification with respect to some historic and systematic aspects.

1 In her target article on “Amusement, Delight, and Whimsy,” Edith Ackermann points out uses of humor and various ways of making sense of our experience that have been underestimated in constructivist discourse, especially in view of tendencies of reduction to hands-on, making stuff, building, or rationalist lopsidedness. In doing so, she refers to a conversation with the late Ernst von Glasersfeld on “the epistemological status of oblique forms of ideation, which resist linguistic or empirical scrutiny” (§32). The subtitle of her target article, “Humor has its reasons that Reason cannot ignore,” makes a good reading in terms of nominalization. On the one hand, the noun-based phrasing or nominal style contrasts with her critical take on philosophical nominalism. On the other hand, it encapsulates the whole argument, or in other words: it boils down her way of reasoning to an essence. Moreover, the subtitle reads like an invitation to variegate it playfully, for example, in the sense of “Why reasoning agents should not ignore humor,” “How witty agents argue conclusively with humor about reasoning,” or “Questioning humorless rationalist reasoning” in the sense of questioning both humorless reasoning of rationalists and editing out the role of humor and also emotions in theories of reasoning and rationality. While sharing a basic appreciation with the author for our friend Ernst’s way of living his theory, I want to highlight some additional aspects of the theme.

2 From a historical perspective, philosophy always was a critique of reason and rationality to a large extent. Thus, a number of ways and modes of criticizing can be distinguished, among them Confucius’s (551–479 BC) way of speaking for wisdom, Isocrates’s (436–338 BC) objections against sophist reasoning and his plea for a rhetoric integrating reason, feeling, and imagination, Jacques Rousseau’s scepticism about benefits from scientific developments, Friedrich Nietzsche’s critique of dynamics of fragmentation of knowledge and alienation in academia, Jean-François Lyotard’s The Differend (1989), Jacques Rancière’s critique of rationality of Disagreement (1999) and his plea for philosophy as praxis, and so forth. In this context, issues of humor and also amusement, delight, and whimsy have been discussed on a number of occasions, too. This pertains to both critique from within, for example, when Lyotard (1989) emphasizes the role of feelings in situations when one is not able to bring forward something, and critique from outside as, for example, the many versions of the story of Thales and the ‘Thracian woman’ show (Blumenberg 2015).

3 Von Glasersfeld referred to constructivism not as something new but rather as a collection of ideas that have not been taken up widely in the European history of thought. Occasionally, he described himself as a kind of “collector of rags,” some of which he kept and put together in a coherent way (Glasersfeld 1994: 39). Although he clearly distinguished between oblique and rational forms of knowing (Glasersfeld 1997), a search for traces in the history of philosophy of all continents regarding alternative conceptualizations of interrelations of various forms of knowing might open up viable options for further development of constructivism.

1 | In Plato’s dialog Theaetetus version Socrates describes the role of a philosopher ironi-
cally: “Why, take the case of Thales, Theodorus. While he was studying the stars and looking up-
wards, he fell into a pit, and a neat, witty Thra-
cian servant girl jeered at him, they say, because he was so eager to know the things in the sky that he could not see what was there before him at his very feet. The same jest applies to all who pass their lives in philosophy” (Plato 1921: 174a).
As to oblique ways of knowing, Ackermann refers to the art of "possibilizing" (Abstract) as a keyword. In my view, this refers not only to important aspects as discussed by means of the emblems of the craftsman, the trickster, and the poet. It also refers to a conceptual terminal (Umschlagplatz), both within constructivist discourse and beyond. Especially in the field of education, similar arguments play a crucial role in basic approaches referring to constructivism. Usually it is the term "didactics of enabling" (Ermöglicherungsdidaktik) that is used in related contexts with respect to the cognitive autonomy of learners and educators, as well as to fictions of control of educational processes (Reich 2008). Nevertheless, too often it remains unclear in the context of educational studies how relations of rational and a-rational dimensions interact, collude, and merge in models and practices of "possibilizing" or "enabling." Accordingly, there remains a need for clarification in the fields of tension of educational processes, educational studies, and educational "science as an art" (Feyerabend 1984).  

Moreover, oblique ways of knowing have not only occupied educators and constructivist thinkers. In my view, Ackermann's argument is relevant in a more general sense, too. On the one hand, it seems to be obvious that there are certain limits – limits of "purposing" (Verzweckung), so to say – to endeavors of successfully instrumentalizing playfulness and the art of "possibilizing." On the other hand, various forms of more or less "pure" reason seem to serve as bearers of hopes throughout history no matter what the effects and impacts of reasoning without humor were. It is precisely tendencies to a "rationalism of disposition" (Verlagungs rationalismus) that is being problematized at this point. I am not referring to one special version of rationalism beside other versions here. Rationalism of disposition refers to all forms of exaltation and superelevation of special forms of rationality. All forms of rationalism become a problem if they go along with a tendency to absolutization of determination of points of departure, assessment, means, purpose, and procedures of intentional fabrication of behavior or societal relationships, including ascription of authority: It is the mode of ignoring humor and the mode of exaltation in terms of claiming privileged framing competences and habitual foregrounding of selected perspectives for all kinds of problems that manifests as a problem consistently. This is one of the reasons why it is important to point up in differentiated and comprehensible ways why reasoning actors should not ignore humor, or in other words, why "humor has its reasons that reason cannot ignore."  

As to re-thinking relations of oblique and rational aspects of knowing in constructivism, integrative perspectives have been formulated at least on an abstract level, for example, by Siegfried Schmidt, who considers dimensions of experience, knowledge, emotion, body, and culture in his conceptualization of perception and cognition as follows:

The rather one-sided observer concept of traditional radical constructivism can be replaced by a more complex one. That is to say, the constructivist's concentration on brain and cognition should be deliberately extended to action, emotion, language, communication, and culture in order to respect not only biological but also socio-cultural acting conditions of human observers. This extension can be legitimated by the fact that observers are, by necessity, emmeshed in social communities and their respective cultural conditions.  

In view of the complex tasks of bridging mindful and playful ways of constructing, rationality and sagacity, emotion and cognition, and humor and reason, as well as designing appropriate forms, further differentiations and inspiring conceptualizations are needed. To my mind, among other points, the following points of contact should turn out to be useful in this context:

1. The interplay between emotion and cognition has been studied particularly in terms of affect-logical dynamics (see Ciompi 1997). Considering correspondences between emotion and thought, and further developments of cognitive science, such as in the affective sciences and cognitive psychology, these approaches have been of increasing interest in recent years. As an example, the concept of "affect-logic," see http://www.ciompi.com/en/affect-logic.html. The concept was introduced in the early 1980s. It refers to interactive dynamics of emotion and cognition in a sense that affective elements show up in all cognitive processes, and elements of logic interact with these affective elements to provide a rich array of complex interactions. The study of these interactions is crucial for understanding human behavior.  

2. For a brief explanation of the concept of "affect-logic," see http://www.ciompi.com/en/affect-logic.html. The concept was introduced in the early 1980s. It refers to interactive dynamics of feeling and thinking or emotion and cognition in a sense that affective elements show up in all cognitive processes, and elements of logic interact with these affective elements to provide a rich array of complex interactions. The study of these interactions is crucial for understanding human behavior.  

3. Currently, terms like "mediation," "mediatization," "mediatization," "mediatization," "mediatization," etc. are used in parallel, sometimes with some degree of overlapping meanings or even synonymously. Depending on research interests and (inter-)disciplinary contexts, various aspects of the importance of media and media dynamics as related to respective fields of study are being foregrounded, all too often waiving thoughtful differentiation or conceptual clarification. Here, in contrast to widespread use of the term "mediatization" in the sense of changing developments of culture, everyday life, or human identity in view of media as technical institutions, the term "mediatization" is used in the sense of media an- thropological and epistemological dimensions of changing media systems and media societies.

http://www.univie.ac.at/constructivism/journal/10/3/405.ackermann
sic ideas of transversal thinking can be helpful in the context of bridging rationality and sagacity if they are liberated from unnecessary purity requirements (Hug & Perger 2000).

"8" Successful dealing with the gap of rationality and sagacity in the multiple sense of acting, thinking and doing everyday business remains a kind of tightrope walk. In corresponding balancing acts, it seems to be wise to distinguish between arts of living – inspired by constructivist ideas – and academic constructivist discourse. Like all -isms, constructivism is not immune against ideological tendencies. But in contrast to truth-oriented -isms, abandonment of claims of privileged access to critique or to reality for undogmatic analysis of relations of different modes of construction and world-making. Insofar as we are aiming at bridging the gap of rationality and sagacity, we should be aware of the long history of endeavors of clarification of rational and a-rational dimensions in science (Duerr 1981). On the one hand, Ackermann’s exploration of “some of the controversies surrounding the evocative power of the imaginal and other oblique forms of knowing” (Abstract) can be read as a focussed analysis by means of emblems of the craftsman, the trickster, and the poet. On the other hand, it points way beyond, towards a delightful critique of pure reason and no less a need for “Re-thinking the enlightenment” (Elkana 2011).

Humor as a Humble Way to Access the Complexity of Knowledge Construction
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> Upshot • Ackermann tackles “humor” as an agentive participant in the process of knowledge construction. Performing her thesis in her writing, she give a reflective account of how oblique ways of knowing have always been present in debates concerning epistemology, albeit not given equal status as rational ones. As such, her endeavors in this text are geared towards lifting up the position of “humor” to a much deserved higher level in educational and learning practices. Consequently, our endeavors in this commentary are targeted towards a little more in this direction by focusing on how “humor” becomes a way of accessing the process of knowledge construction and of unraveling its significance.

"1” In her target article “Amusement, delight, and whimsy: Humor has its reasons that reason cannot ignore” Edith Ackermann writes passionately about an alternative perspective in embracing constructivism – a perspective that takes attention away from an individual learner’s mind working on its own on pre-determined paths of knowing and employs rationality as the main way of being able to construct knowledge. Instead, Ackermann invites us to approach rational and irrational, mindful and mindless, thinking and playing, logic and emotion, sense and nonsense as the two sides of the same coin. For this task, she applies “humor” as both wit and whimsy and brings forward the qualities of openness, pleasure and joy that elevate the necessary energies released by a creative innovator. Quite provocatively, and yet convincingly, Ackermann echoes how Jacques Ranciere (1991) delves into intellec- tual emancipation in his well-known book *The Ignorant Schoolmaster* when she insists that “knowing gets in the way” (§8) and that “the more we know the more likely we are to act mindlessly” (§8). However, her aim, in the context of this text, is not to practice philosophy, but, more, to aggrivate, inflate and challenge what “traditional” constructionism might take for granted about cognition, cognitive adaptation and cognitive growth as the most essential human acts. As she de-notes in the very last line before drawing her concluding remarks:

“*At the cost of caricaturing, let me put it this way: fellow constructivists sometimes seem to ignore that, once launched, a human artifact takes on a life on its own, thus transcending both the author’s intentions and any singular act of interpretation.”*(§31)

It is this particular statement that becomes a gesture of an epistemological stance that urges us to shift from an individual perspective of the learner as a sole constructor of knowledge and to turn towards denoting the ultimate importance of recognizing the unexpected, the non-knowable, the not-yet-known or the surprising effect of any attempt to do, make, construct and create. Humor, as an archetype of body-language related to the unconscious, seems to have been always tightly situated in such complex processes. Its recognition requires that we take a careful, deep and respectful look at how participants experience the context in which they enact.

“2” Humor has also been reported in a recent study contacted by the first author (Chronaki & Matos 2013) as an essential element of how teachers appropriate technology whilst they become involved in identity-work re-crafting mathematical sub-jectivities. Specifically, during the last phase of a three-month intensive training course for teachers’ professional development in technology-based teaching and learning, a small team of mathematics teacher trainees and their tutors discussed – as a way of collective reflection – the significance of the particular course for themselves as practitioners. Their focus soon shifted to the kind of “changes” they had experienced. When asked about how they experienced “change,” one teacher said in a kind of humorous way:
They talked about “change” as a virtue that cannot be genuinely achieved or caught through the dilemmas raised as part of everyday school reality. Humor, then, was way for them to denote this incongruity and to cope with the uncertainty of having to deal with the utopian experience of “change”:

“Teacher P: You shouldn’t ask me, because you see me. At least myself, I was at a different phase at the beginning and I have now developed. I understood what you wanted, then I questioned it, then I was convinced and I, now, hold on to what I personally want from what you questioned it, then I was convinced and I, now,” (Chronaki & Matos 2013: 107)

“In our case, Teacher K and his colleagues seem to have this “joking license” to talk about “change” and laugh about the incomplete process of changing towards a “new” mathematics teacher identity. The significance of this humorous event points out a shared concern amongst teachers that aims to disturb the stereotypical image of the computer as a “mythical” and “heroic” mediator for enhancing change in mathematical school life and culture. It further indicates their experience of “identity change” as a complex and slippery process, with ups and downs, risks and ambivalences – a process that envelops strain, fear, and uncertainty. As Victor Raskin (1985) explains, humor is based on incongruity and in particular at the degree of inconsistency or distance that exists amongst how things are and how we would have liked them to be. Teachers’ humor, thus, highlights the “gap” between the actual and designated phases of their becoming computer or maths teacher trainers. As such, it also indicates the reinforcement of a specific desire. As Tony Brown and Olwen McNamara suggest, referring to Jacques Lacan, “[...the distance between life and its supposed symbolization must not be obliterated. This very gap creates the desire and shapes life itself” (Brown & McNamara 2005: 35).
Author’s Response:
Impenetrable Minds, Delusion of Shared Experience:
Let’s Pretend (“diciamo che io ero la mamma”)
Edith K. Ackermann

> Upshot - In view of Kenny’s clinical insights, Hug’s notes on the intricacies of rational vs. a-rational “knowing” in the design sciences, and Chronaki & Kynigos’s notice of mathematics teachers’ meta-communication on experiences of change, this response reframes the heuristic power of dislocation and suspension of disbelief in the light of Kelly’s notion of “as-if-ism” (constructive alternativism). Doing as-if and playing what-if, I reiterate, are critical to mitigating intra-and inter-personal relations, or meta-communicating. Their epistemic status within the radical constructivist framework is cast in the context of mutually enriching conversational techniques, or language-games, inspired by Maturana’s concepts of “objectivity in parenthesis” and the multiverse.

Introduction

1 Cognizant of the unintelligibility of our own and other people’s experience, and the sinuous paths by which we come to know – and grow in connection with others, constructive alternativism and parenthetical objectivity loosen radical constructivisms claims-to-rational-knowing by examining intelligent beings’ abilities to con-verse, or co-drift “within reason.” Astute conversationalists give each other license to embark on seemingly unnecessary detours and regressions (musings), to shift “gears” (in and out of pretense, of focus, of character), and to be of more than one mind (hold conflicting views) or mood (emotion). Whether children or scientists, they welcome thoughts that seem to pop out of nowhere, provided the intruders (move or mood) spark enough interest to take a next step! As they co-drift, conversationalists create their own “invented” realities, and

where [...] That this is so is apparent in situations that startle us.17 (Maturana 1988b: 261)

Invented realities – taken-as shared experience/suspended claims-to-knowing

2 In his commentary, Vincent Kenny eloquently argues that the limits we set on radical constructivists’ claims-to-rational-knowing go far beyond what counts as legitimate within in a scientific community. The problem, instead, derives from the radical constructivist (RC) position that we cannot, as humans, share our experience. Such a stance itself puts us in a bind if left unexamined. Let me explain.

3 As constructivists, we “know” that we can never fully understand others or be understood by them. We also “know” that our experiences in the world – and the world in which we operate – are impenetrable, except through the distinctions that we establish in conjunction to our own privately felt encounters, or touch points. George Kelly and Hans Vaihinger’s constructive alternativism (as-if-ism) and Humberto Maturana’s objectivity-in-parenthesis (personal reality) help revive the idea that playing by our own made-up rules (including taken-as-shared experience, common ground) is a condition sine qua non in the pursuit of mutually enriching intra-or inter-personal transactions, whether for children, or scientists. In my words, no conversation can be held, or knowledge construed, without tentative attributions and negotiation of taken-as-shared ground. This does not entail that we need to get trapped into the delusion of shared experience. The very construction of cognitive invariants, as defined by Jean Piaget, is a developing child’s means to momentarily hold still what she previously made up, whether intentionally or not. Beyond the construction of object permanency (“I make you exist because you are there for me), a pretending child’s “diciamo che io ero la mamma”2 is a 3–4 year-old’s own way of inverting her invented realities through suspension of disbelief and meta-communication. And this in turn helps shake off previously held assertions that kept her in place before she could safely leap into the unknown.

Epistemic reframing: Se non è vero è ben trovato! (even if it’s untrue, it’s well conceived)

4 The “construct” of taken-as shared experience serves as a fiction that helps us in our relations with others. Yet, as Kenny argues, relying on our “invented realities” comes at a price if we forget that we have construed them in the first place. In other words, the more we mistake our attributions as things in themselves (in this case, commonalities among fellow humans), the more readily we jump into WE-ifying – and reifying – any contingent manifestations of our own and other people’s private experiences. In §8, Kenny writes:

5 When the ‘illusion of sharing’ comes unstuck, people run into difficulty and begin to elaborate ‘solutions’ in relation to the threat of the loss of this illusion. In therapy, two of the most extreme manifestations are presented by, on the one hand, the person who is mistakenly seeking a profoundly symbiotic relationship (‘merging’ solves the ‘sharing’ dilemma – ‘losing oneself’ in another) and, on the other hand, by the person who gets labeled ‘schizophrenic’ (taking the impossibility of ‘sharing’ to the extreme of a ‘schism’ of the distinction of an internal vs. external reality – ‘losing oneself’ in oneself) and ceasing to engage in the meta-communication (Bateson 1991b: 149) necessary to coordinate activities with others.5

6 Constructive alternativism offers a way out of the bind by pointing out that we should feel free, as constructivists, to act as-if our constructions are true while realizing that they are no more than tentative hypothesis that can be revised and discarded at any time. Such speculative exploration and playful negotiation of personal constructions offer a refreshing alternative to decades of analytic search for objective truths based on a quest for certainty. It opens up new ways to a radical constructivist psychology of mutual understanding through the consensual mitigation of privately held experiences, in situ.

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5 In English, “Let’s say I was the mama.” This was the title of a presentation by Francesca Archinto and myself at the 2001 workshop on Narrative Intelligence, organized by Andreas Wigand and Daniele Bresciani, LEGO A/S in Cassinazza-Orsenigo, Italy.
Science of design, praxis of living, art of possibilizing

« 6 » There are many ways of making sense of our experience, not all of which are equally validated by RC’s claims to rational knowing. As Theo Hug notes, what still remains unclear, especially in the fields of ed- and cons, which I touch upon shortly. One tendency among RC disciples, alluded to by Hug, is to cast design and educational trans-actions as special cases of scientific inquiry (Krippendorff 2006). Another, brought forth by Maria Chronaki and Chronis Kynigos’s note on teachers’ meta-communicating (on their own perceptions of change) is to acknowled-ge the constructive “messiness” inherent to the scientific process itself (Kelly, Bateson, Maturana, Kenny). Each comes with its pros and cons, which I touch upon shortly.

« 7 » In response to Hug’s §7, let me sug-gest that Klaus Krippendorff’s constructivist design theory (2006) legitimizes the “scienti-city” of design inquiry as long as the sciences it claims to pertain to are themselves moving away from modeling “what is” and able to provide the tools and techniques to engender new possibilities and engender desirable changes. Krippendorff outlines several characteristics that, in his view, are unique to the design sciences, including de-signers’ emphasis on:

• building artifacts that did not exist be-fore (thus a need to prioritize variability over generalization);
• getting a sense of the past and present conditions, of which projected futures may constitute improvements (through playing out varying scenarios);
• understanding how designers’ percep-tion of other stakeholders’ understand-ings may inform the design process (thus calling for self-scrutiny and other reframing techniques); and lastly
• substantiating and validating claims for proposed designs (through proof of concept and argumentation).

« 8 » In response to Chronaki & Kyni-go’s §§2–5, let me underscore that George Kelly, Gregory Bateson, and Humberto Maturana, for their part, relinquish control altogether and acknowledge both the consensual and speculative nature of any form of knowledge construction. In other words, knowledge-in-the-becoming, scientific or otherwise, may be best understood as the sight-provoking give-and-takes between intelligent conversationalists, who, not unlike dancers, know not to predict or force their way as they drift. Instead, they jointly en-gender and possibly harmonize each others’ moves, knowing that whatever they bring to the table, or the dance floor, becomes part of the medium in which they operate, thus tak-ing them in a different direction than they would have taken had they done nothing or something else (Kenny 1989).

Toward an epistemology of the living: Objectivity in brackets, multiversa

« 9 » Maturana describes the assump-tion of an objective reality as a “miss-take,” i.e., of erroneously taking as independent our invented realities based on a quest for certainty, and warns that “certainty blinds, the more certainty the less you see” (cited in Kenny 1989). Maturana also helps refine scientific claims of rational knowing by sug-gest-ing a rather forgiving pathway, or epis-temological stance, which he refers to as “objectivity in parenthesis.” In the case of objectivity without parenthesis, we “know” it: the observer assumes that objects in the world have a separate existence, indepen-dent of who we are or what we do, and can be apprehended through perceiving, reason-ing, or instruction. In the case of bracketed objectivity, the observer abandons the myth of privileged access to an objective reality, and engages with the world as a multiverse, only tentatively and parenthetically endow-ing people and things with projected attrib-utes (pretending they exist independently). Maturana defines multiverse as a multi-path, intertwined, ever changing eco-system in which multiple “realities” can be brought forth depending on the distinctions of the observer. He writes:

This consensual view of knowing-in-the-becoming allows for multiple forms of ra-tionalities.

Conclusion

« 10 » Ernst von Glasersfeld saw ratio-nal, poetic, and mystic modes of knowing as incompatible. Kelly, in contrast, advocated that alternative modes of experiencing (in this case, “coming to see anew” through suspension of disbelief) be given equal epis-temological status (Kelly 1955: 83) – which I take as a radical constructivist’s acknowledg-ement that scientists, like clinicians, may have good reasons to embrace thoughts that cannot easily be derived from one from the other in order to hold on to conflicting views or dwell into what feels worth purs-uing, even if unclear. Scientists, likewise, carefully choose what to say or leave unspoken – and how to say it and when – so that colleagues, friends, or clients can take a next step and forge their own understandings. And as Kelly noted before Kenny:

**Nowhere is this semantic enslavement clearer than in the psychotherapy room. It is there one can see most clearly how man can be trapped by his indicative verbs and how, in turn, he has been led to believe that he must choose between mutually exclusive versions of reality.”** (Kelly 1969: 162)

« 11 » Introducing whimsy, humor, and amusement as a means of making sense of our own – and other people’s – experience has been my own attempt at bridging alleg-edly incompatible domains, such as child’s fantasy play and scientific investigation, using Arthur Koestler’s theory of biosocia- tion. Kelly’s constructive alternativism and Maturana’s multiverse, as well as Krippen-dorf’s revisitation of existing design theory offer further insights for RCs themselves to avoid getting ‘bogged down’ in the rational-ist “logic” of misguided anticipatory reason-ing and after-the-fact rationalization. Kelly’s as-if-ism encourages us to maintain a con-junctural pose as often as possible, so we can extricate ourselves from our own construed realities (which, once they become second nature, we tend to see as external realities). Maturana’s conversational theory further highlights that any explanation or descrip-tion of what we do is secondary to our ex-
experience of finding ourselves in the doing of what we do. Indeed, whatever happens to us, happens to us as an experience that we live as coming from nowhere (Maturana 1988b: 26). I thank my commentators Vincent, Theo, Maria and Chronis for helping me get back to my RC roots and revisit some of my own tentative assumptions.

Received: 24 June 2015
Accepted: 30 June 2015

Combined References


http://www.univie.ac.at/constructivism/journal/10/3/405.ackermann
In his review of *The Embodied Mind* (1991), self-proclaimed “ardent reformer” of cognitive science Daniel Dennett provisionally celebrates the book for “executing what is surely the best informed, best balanced radical critique [of cognitive science] to date” (Dennett 1993). Though grateful for the “important nudges” Francisco Varela, Evan Thompson, and Eleanor Rosch provide him, "nudges away from admittedly deplorable, but optional, features of cog-sci dogma," Dennett is nevertheless unconvinced that the enactive approach accomplishes a revolution: “Reform, as we know, is the enemy of revolution, and as an ardent reformer, I must say that they have not convinced me.” “It is too soon to say” whether the “enactivist enlightenment” is capable of eventuating the radical changes it proposes, Dennett concludes, “so we will not know for a while whether we need or are in the midst of, a revolution in cognitive science. In the meantime, the authors find many new ways of putting together old points that we knew were true but did not know what to do with, and that in itself is a major contribution to our understanding of cognitive science.”

(Dennett 1993: 125f)

Dennett’s review was written over twenty years ago. One can hardly doubt that since the advent of *The Embodied Mind* the enactive movement has grown steadily stronger, but has it achieved a revolutionary shift in cognitive science? Tom Froese suggests that while Dennett was right twenty years ago, the new conceptual foundation of sense-making and various advances in enactive cognitive science evince the fruits of a revolution. Thus "we can finally say that Dennett was wrong in thinking that the enactive approach would be unable to address higher-level cognition without falling back on the notion of mental representation” (Froese 2011: 210). While Dennett thinks revolution is the enemy of reform, Ezequiel Di Paolo insists in a recent talk! that reform is rather the enemy of revolution, in that certain questions – often questions, I would add, concerning embodied encounters with non-sense – are ever relegated by cognitivist frameworks. Entrenched representationalist and internalist assumptions exclude radical questions that challenge these foundations, thus the exigency of overcoming cognitivism rather than gradually reforming its tacit and explicit assumptions.

A host of the pressing questions excluded by cognitivism are addressed in *Enactive Science at the Edge of Sense-Making,* which evinces the movement’s theoretical, practical, cultural, and therapeutic attempts to progress toward greater specification and validation of its revolutionary penchant and program, especially regarding the higher-level cognitive processes of second-order sense-making. Though the collection exemplifies the conceptual sophistication achieved and experimental support garnered for the enactive approach since the early 1990s, it also heeds obstacles and occlusions still to be dealt with, perhaps before the veracity of Dennett’s review fades away. *The Embodied Mind* made sweeping pro-grammatic suggestions spanning previously quite disparate disciplines and traditions. Many of their sources of inspiration and influence are taken up in *Enactive Science at the Edge of Sense-Making.*


The enactive approach is a multi-disciplinary response to the biological, existential, social, ecological, and creative exigencies of personal experience that the cognitivist approach will not accommodate due to its avowedly sub-personal level of orientation. Many find the multiplicity of the enactive approach and its attention to personal experience attractive, especially in the wake of the dominance of cognitivism. On the bright side, the expansiveness of the enactivist tent is (at least minimally) amenable to many backgrounds, and so able to attract potential revolutionaries. With one foot in the door, “one could well be an enactivist without realizing it,” as Dennett quips (1993). The movement’s concomitant susceptibility to inner ambiguities, conflicts, and confusions intensifies the challenge of competing with cognitivist theories and research programs, and so may simultaneously trouble likely sympathizers. Nevertheless, there are indeed some widely shared assumptions, which the editors of the collection, Tom Froese and Massimiliano Cappuccio, discuss in their introduction in

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1 | “Enaction, embodiment and the social invisible” (2012). https://ezequieldipaolo.wordpress.com/media/
careful and compelling style, as they situate the features and relevance of the enactive theory of sense-making and its relation to non-sense within the greater program. “This book asks the sciences of the mind,” according to the editors, “to test their own boundaries, demanding that they account for a number of cognitive and experiential phenomena that are at the edge of the very possibility to cognize” (29). If I were to pin down a thesis statement summing up the collection’s conclusions regarding non-sense – that ever-changing and always relatively elusive threshold of sense-making – I would be performatively inconsistent with its topic. The various approaches to non-sense elaborated in this collection “are timely and challenging, precisely because they don’t attempt simplifications that may ultimately prove senseless,” as Di Paolo sums up his eloquent foreword. The topic of the book performs a humble awareness of the myriad problems facing any pretension to comprehensiveness in the complex of fields related to cognitive theory and science. I can safely summate, nonetheless, that in their accounts of the various transitions from non-sense to sense (and vice-versa), and more radically of the very possibility of non-sense as such, the authors do not restrict non-sense to a failure of adaptive know-how or of individual or social sense-making capacities. Often experiences of non-sense are celebrated as occasions for creativity and therapeutic becoming.

In order to prevent potential confusion, it is of course important for enactivism continually to make nuanced sense of the word “enaction,” which is not univocal across different discourses claiming allegiance to the movement. A brief etymology, emphasizing moments in its history especially relevant to Constructivist Foundations, and the specifics of its employment within this compendium, is necessary before I summarize the authors’ respective contributions. The term was first popularized, as Kevin McGee has discussed, by constructivist cognitive scientist Jerome Bruner to name a certain way to “translate experience into a model of the world” (McGee 2005, 20). In other words, a certain “mental model” of an everyday activity (e.g., riding a bicycle) results not from second-order reflective processes but through the first-order activity the mental model enacts. The term was first employed to describe a kind of cognitive science by Varela, Thompson, and Rosch wishing to emphasize a fundamental insight of radical constructivism, “to emphasize the growing conviction that cognition is not the representation of a pregiven world by a pregiven mind but is rather the enactment of a world and a mind on the basis of a history of the variety of actions that a being in the world performs. The enactive approach takes seriously, then, the philosophical critique of the idea that the mind is a mirror of nature but goes further by addressing this issue from within the heartland of science” (Varela, Thompson, Rosch 1991: 10). As McGee cautions, affirmative references to their approach and usage of “enactive cognition” and “enaction” do not always entail a radical constructivist framework (McGee 2005: 20). The contributions to Enactive Cognition at the Edge of Sense-Making seem, to varying degrees, aligned with radical constructivism, and though I attempt to highlight salient aspects of the essays suggestive of where they may stand in relation to it, I leave ultimate judgments regarding specific chapters up to the reader. As I move on to specifying the enactivist orientation, McGee’s very detailed essays (2005, 2006) introducing enactive cognitive science in explicit relation to radical constructivism are highly recommended for readers of this review wishing for a more thorough treatment of this relation.

This multidirectional collection of essays explicates and indeed enacts the conceptual constellation characteristic of the enactive approach, as Froese and Cappuccio enumerate: (1) dynamical systems (including emergence); (2) biological autonomy (including autopoiesis); (3) embodiment (with environmental embeddedness); (4) experience (emphasizing phenomenological concerns and accounts); and especially (5) sense-making and its relation to non-sense. Enactivism is not opposed to studying the sub-personal dimensions of human life, those dimensions ineluctably hidden from experience. Its revolutionary penchant is to study personal experience in juxtaposition with the study of the sub-personal. Thus enactivist science is inextricably entwined with enactivist philosophy. Though its epistemic constructs and research programs are quite diverse – occasionally in tacit, if not explicit, conflict – the enactive approach is at present not only unified in its attempt to articulate the patterns of daily experience. It also attempts to articulate profoundly affective liminal experiences and subsequent second-order cognitions attempting to make sense of them. These experiences, surely familiar in their unfamiliarity to the Constructivist Foundations community, prime readers for the sense (and non-sense) of existence articulated by the writers of this volume and others attuned to the enactivist orientation. At stake in this book are the theoretical foundations of higher-level cognition as sense-making (21). Pervasive is its consideration of questions surrounding an ever-puzzling paradox: the human capacity to perceive the nonsensical depends on our perpetual attempt to make sense of the nonsensical. Or to pose the paradox otherwise, as Cappuccio and Froese do: “…if sense-making is just the possibility of our mind to adhere to familiar situations and contexts and to dynamically adjust them, then what adherence or adjustment could possibility make sense of the absurdity of those situations in which no adherence or adjustment seems possible” (22)? This paradox reaches a fever pitch when sense poses the question concerning non-sense as such. In what follows I give all-too-brief though hopefully suggestive summaries of the essays comprising the collection, appealing to aspects salient to the prospective readers of Constructivist Foundations.

Part 1 Theory and method

In “Breaking the Perception-Action Cycle: Experimental Phenomenology of Non-Sense and Its Implications for theories of Perception and Movement Science,” Dobromir Dotov & Anthony Chemero suggest that (1) conjunctions of perception and action initiate all instances of cognition (hence “perception-action”), and (2) similar to the shift from Zuhandenheit to Vorhandenheit involved in the breakdown of Martin Heidegger’s hammer, “cognition arises out of frustration, when an agent confronts non-sense” (37). Being and Time’s tool analysis plays an explicit role in their presentation of an experimental paradigm, the current results of which indicate that perception-action of ready-to-hand experience is a fluid process giving way to cognition only when this process is interrupted by non-sense. For the aesthetically inclined, Maurice Merleau-Ponty's
fascinating phenomenological descriptions of Paul Cezanne's creative process (in an essay of 1945, “Cezanne's Doubt”) give a more dynamic sense of how non-sense is constitutive of any cognition than does Heidegger's hammering. Cezanne created in a state of “mental agitation,” attempting the impossible task of eliciting in the recipient a perceptual experience not of the static world in paint, but of the world itself, in all its dynamism, aided or initiated by Cezanne's painting. Dotov and Chemero also explore an experimental paradigm that “front-loads” these phenomenological influences, the results of which “reinforce the distinction between tools and being experienced as ready-to-hand and turning into unready- or present-at-hand when sense-making was thwarted” (37). The latter elicited a more cognitive approach towards the tasks involved in the experiments. Curiously, Heidegger drops the distinction between Zuhandenheit and Vorhandenheit after Being and Time. Critical engagement with this chapter, and with the general tendency in enactive theory to elaborate these specific analyses of Being and Time, may turn on an appeal to the later Heidegger's writings on the thing – a quite different approach at human sense-making and worldly situatedness. From its very beginnings, enactivism has drawn on both Eastern and Western philosophical, religious, and scientific orientations. Michel Bitbol’s “Making Sense of Non-Sense in Physics: The Quantum Koan” prescribes the therapeutic and meditative balms of Zen Buddhism to Western culture's predominant penchant, its relentless “bias,” to make representation(s) a paradigm of sense-making, “even in cases like quantum physics where this looks problematic” (61). Bitbol’s “synergy” of these unique traditions – differences between which he neither collapses nor minimizes – celebrates the scientist as an always already situated agent attempting to think through the non-sense encountered by the problematic of quantum physics through embodied Zen practices. These problematic challenges objectivist and naturalist assumptions presupposing representationalist epistemologies. Bitbol also provides helpful contextualization of his proposal with regard to the trajectory of enactivist theory.

Turning from human sense-making to that of our closest living relatives, David Leavens provides a selective review of research regarding “object-choice tasks,” whereby “participants use directional cues to find hidden objects” (81). “The Plight of the Sense-Making Ape” elaborates upon the data's suggestion that apes are equally capable of making sense of simple directional cues or social signals as human children. On this basis, Leavens critiques the ubiquity of scientific claims attributing a superior set of innate cognitive capacities to humans over great apes, therein underestimating the plasticity shared by both lineages (98f). Leavens's chapter is an excellent reminder that issues of sense and non-sense, though typically considered specific to the human species, should be addressed in relation to other species.

Advocating an approach to immunology based not on the classical model of a “linear input-output system” that destroys everything it perceives (with the exception only of its own body) but rather on the concept of auto poiesis, John Stewart presents “computer simulations based on a mathematical model of an idiocytic network, which involves morphogenesis in shape-space” (105). Stewart elaborates their implications for sense making on the higher-level of abstraction associated with the respective value judgments tied to the theoretical-epistemological choice one makes between the classical and autopoietic paradigms. To express the autopoietic process of the immune system, Stewart appeals to a verse of Portuguese poet Fernando Pessoa: What we see / Is not what we see / But what we are. Stewart's epistemological discussion unfurls this verse. Does “we” in Pessoa's verse refer – for Stewart – only to human immune systems, or also to human social cognition? Of utmost importance is an ambiguity Stewart's essay leaves utterly unattended: To what extent, if at all, are human beings autopoietic systems? Humberto Maturana, for example, is avowedly unsure. Stewart seems committed to an affirmative answer, considering that he advocates a transition from first- to second-order processes, i.e., from immune to cognitive sense-making processes, without clarifying whether the latter is grounded or whether it is also determined by auto poiesis, without accounting for autopoietic differences respective of the orders if indeed sense-making is grounded and determined by some kind of auto poiesis.

Stewart summarizes the historical development of this new paradigm in immunology, which includes his work with Varela. Appealing to Thomas Kuhn's principle of incommensurability, Stewart admits that no empirical research can decide between the classical and autopoietic paradigms. Thus the choice concerns “values.” Is it possible to make the “hidden values” involved in choosing between the classical and autopoietic paradigms of immunology (120)? What values are at stake in such a choice? Stewart concludes by suggesting that concern with the human capacity for “making sense” is addressed when we figure out how to study these values.

Part 2 Experience and psychopathology

In “The Surprise of Non-Sense,” Natalie Depraz brings the systematic results of her previous research on surprise to bear on myriad experiences of non-sense. She weaves the affective temporality of surprise with these various modes of non-sense, showing how they are inextricably entwined, “how they reciprocally enlighten and extend each other anew” (125). Her philosophically nuanced chapter achieves an impressive convergence of a phenomenology of these mutually influencing relations and an enactive framework – what she calls a “generative relationship.” While other chapters develop insights from Heidegger and Merleau-Ponty, Depraz ventures back to the father of phenomenology, Edmund Husserl, for his investigations into the emotion of surprise, which she juxtaposes with the latter’s phenomenologies of the uncanny.

Readers attuned to analytic philosophy of mind may wish to turn directly to Michael Beaton's rich essay, “Learning to Perceive What We Do Not Yet Understand: Letting the World Guide Us.” Beaton presents an enactivist, conceptualist, and direct realist theory of perception avowedly augmenting Nøe and O'Regan's sensorimotor contingency theory of perception. He defends the thesis that “we can only perceive what we understand” while assuaging concerns regarding what seems a concomitant incapacity to perceive the new, the not-yet understood. His non-representational approach – in the wake of Immanuel Kant, Peter Sellars, W. V. O. Quine, David Davidson, John McDowell, and others – eventually attempts to account for how, through perceptual learning, “the
world itself guides our understanding, as we move from non-sense to sense” (153). In cases of transition more easily accounted for by Beaton’s orientation, outlines of our inadequate understanding of relatively novel interactions with the world guide us in our gradual assimilation of better coordinates with the world. Beaton intriguingly discusses how, in this transitional process, personal-level insights guide subpersonal perceptual interaction at thresholds of non-sense, and how in implicit perceptual learning – the harder cases – aspects of the world guide our interaction where personal-level explanation terminates.

In “No Non-Sense Without Imagination: Schizophrenic Delusion as Reified Imaginings Unchallengeable by Perception,” Daria Dibitonto brings a phenomenological psychology of imagination to bear on the task of not only describing, but also explaining, the transition from “prodromal disembodiment to acute schizophrenic symptoms (hallucinations and delusions);” and how perception cannot challenge the reified imaginings of schizophrenic delusion (181). Dibitonto discusses more generally how the enactive approach to psychopathology shows that the imagination is a precondition (1) of radical experiences of non-sense and (2) of making sense of non-sense in “embodied and embedded psychotherapies” (181).

### Part 3 Language and culture

Elena Clare Cuffari’s chapter, “On Being Mindful about Misunderstandings in Languaging: Making Sense of Non-Sense as the Way to Sharing Linguistic Meaning,” heeds and joins Di Paolo (2005), Froese, and Stewart (2010, 2012) in critically engaging and augmenting Maturana’s accounts of languaging. She elaborates the dynamic shifts from pre-communicative non-sense to common sense-making in the creative act of converging, of participatory sense-making. Cuffari details what she considers the conditions of possibility for meaning creation in illuminating fashion, covering much ground along the way. She addresses the aforementioned paradox of sense and non-sense – crucial to this collection – by showing how instances of linguistic understanding tacitly depend on the precariousness of understanding, on the great potential for misunderstanding.

William Short, Wilson Shearin, and Alistair Welchman offer an approach to sense and non-sense developed in the fruitful fusion of philosophy and literature. The authors of “Deleuze and the Enaction of Non-Sense” provide (1) a very cogent overview of embodied and enactive theories of linguistic sense-making; (2) a critical reading of Gilles Deleuze’s analysis of Lewis Carroll’s portmanteau creations of non-sense in The Logic of Sense, in which they argue that it “remains broadly within the tradition of embodiment” (239); (3) an affirmative reading of Deleuze’s later encounter with the notoriously nonsensical works of Antonin Artaud that exhibits a more radical enactive concept of linguistic meaning; and (4) the authors make allusions to Deleuze’s work with Félix Guattari, specifically Anti-Oedipus, in an effort to indicate the great relevance of Deleuze’s robust conceptual resources to enactive approaches to linguistic sense-making, especially when language encounters the advent of the new, of the nonsensical.

Much can be learned from ancient wisdom traditions and shamanic techniques long cultivated for the sake of encountering and configuring non-sense into reconfigurational meanings for the purposes of healing and enhancing the wisdom of individuals and collectives. In “Traditional Shamanism as Embodied Expertise on Sense and Non-Sense” Juan González elaborates the case of traditional Huichol shamanism and its consciousness-modifying peyote rituals through sophisticated philosophical and scientific reconceptualization. Shamanic expertise can lead to an “existentially mature society” capable of transforming especially ritual but also everyday experiences of non-sense into previously held belief-systems, cosmologies, and social techniques for the physical and mental betterment of society (283).

Gender is a complex form of sense-making. It is a multifaceted system that affects and is affected by sociocultural environments, shaping and subtending cognitive processes and so-called “mental institutions.” Michele Merritt’s “Making (Non)sense of Gender” discusses “gender breakdown,” e.g., gender misidentification, in terms of sense-making breakdowns – though in far more complex ways than those associated with breakdowns in tool-use. Thus Merritt sets out to develop a more nuanced notion of breakdown focused more on the inter- and intra-personal aspects of social sense-making.

### Conclusion

Enactivists, in closing, never tire of emphasizing the exigency of overcoming internalist and representationalist thinking and resultant praxes, and rightfully so, for no matter how slowly such attempts gain traction, these incessant dualistic tendencies seep deeply affecting and perceptual relations to others, to local and evermore encompassing environments, to plant and animal life systems, and to our own personal trajectories of sense-making and social becoming in relation to varieties of non-sense. It is surely too simplistic to judge the enactive theory and science of cognition in terms of achievements of revolution or reform, but aspirations toward the former catalyze an enthusiasm that cannot be overlooked in this book and others associated with the enactive approach.

### References


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Received: 10 May 2015
Accepted: 11 June 2015

http://www.univie.ac.at/constructivism/journal/10/3/422.hoburg
Computational Explanation in Cognitive Sciences: The Mechanist Turn

Over the past decades, computationalism, or the computational theory of mind, has received a lot of attention. It is often assumed that this theory, that under the most widespread model claims that the mind resembles a digital computer, is the main working hypothesis of cognitive science. In Explaining the Computational Mind, Marcin Milkowski gives a discussion of computational explanations of cognition, focusing on the question of whether and how computational models are successful in explaining the mental process. More precisely, Milkowski points out that most accounts are either too limited in scope or too vague, leaving it far from clear what is meant by computation. It seems, furthermore, that philosophers and practicing scientists do not always use these notions in a similar way. What his book contributes to the extensive literature is an attempt to disentangle some of the confusion left by the various accounts. He then goes on to offer and defend a mechanistic approach to computational explanation, resulting in a view that is explicit enough to ensure empirical adequacy. The role of mechanisms is crucial for Milkowski. He stresses throughout that cognition has at least one essential level of organization that is best described as information processing, or computation, but that a computational explanation cannot be complete without a mechanistic account of its implementation and embedding in an environment.

Explaining the Computational Mind

The first chapter of the book, “Computation in cognitive Science: Four Case studies and a Funeral,” addresses the notion of computation in cognitive science. Computation is often reduced to only one of its models, namely the classical computational simulation, belonging to the logical-symbolic tradition. While cognitive scientists used to appeal almost exclusively to such computer models in order to get a grip on cognition, many scientists in the field have shifted towards dynamical models. The traditional computational mind has even been rejected to a certain extent, raising the idea that a funeral for computationalism is imminent. Milkowski convincingly averts this pending funeral by widening the scope of computational cognition. He sees any computational theory as an account of how information is processed in the system under investigation. Following such an approach enables him to discuss four case studies that each (re)present a dissimilar model of computational cognition: (1) classical computational simulation, (2) connectionist modeling, (3) computational neuroscience and (4) radical embedded robotics. What emerges from this chapter is that cognitive scientists employ a wide range of computational models. In Chapter 5, he argues that dynamical systems are yet another (fifth) strategy that is nonetheless computational. The scope and form of efficiency of a computational explanation varies with each strategy.

In the second chapter, “Computational Processes,” Milkowski states that computation is and should be equated with information processing, transforming a stream of input information into a stream of information as the output. Information, which may be digital or analog in this account, need not be representational and does not presuppose any model of computation. He then goes on to analyse what it means for a physical process to realize or implement a computation. Diverse philosophical treatments of implementation are discussed. Milkowski shows how both the single mapping account (of early functionalism) and semantic or formal symbol accounts fail to convey how its theoretical entities are more than in the eye of the beholder, and thus cannot be considered explanatory. Furthermore, both suffer from trivialization, as shown by Putnam, who argues that any open physical system can implement any computation, and by Searle,
who claims that any syntactical object has a description under which it is implementing a program. Since these views are unsatisfactory, Milkowski carefully proposes his mechanistic account. He argues that a computational account needs an explication of its organization and its boundaries in order to clarify the proper mapping of a mathematical model to a physical process. A mechanistic account of implementation realizes computational functions by its underlying mechanism, meaning the organization of its causal structure. A computational mechanism consists of at least three levels of organization: contextual, isolated and constitutive organization. For cognitive systems, the contextual level of organization includes general cognitive mechanisms and the environment of the system; the isolated level of organization features the computational processes that contribute to cognitive processes; and the constitutive level of organization describes the structures that realize the computation. A crucial aspect of Milkowski's view is that the lowest, constitutive, level is itself not computational. Consequently, computational mechanisms will bottom out in non-computational structures. What is required are the proper interlevel relationships, making it impossible to have arbitrary ascriptions of computation that are not grounded in lower levels.

The third chapter, “Computational Explanation,” turns to the explanatory role of computational approaches. In accordance with the first two chapters, the essential characteristic of explanation is taken to be the transformation of information. In the literature there are two dominant theories of computational explanation, a functionalist and a mechanistic approach. Surprisingly, Milkowski addresses first the deductive-nomological or covering-law model. This classical model of explanation, founded by Carl Hempel and Paul Oppenheim, has received a fair amount of criticism in the philosophy of explanation, certainly in discussions on explanations outside physics, resulting in more diverse and detailed accounts of explanation. Although Milkowski gives an interesting discussion of this model in cognitive science, it is no surprise that it fails to be an adequate account. At this point it is no revelation either that Milkowski finds the mechanistic framework superior to the functionalist approach for explicating computation. By taking the four case studies discussed in Chapter 2 as evidence, he argues that David Marr's functionalist approach is missing real mechanistic organization. The functionalist account also starts from multiple levels, namely a computational level, a level of representation and algorithm and a level of hardware implementation. The problem, and main argument of this book, is that this account does not require causal relevance of the algorithm and representation level. The only requirement is sufficiency. The mechanistic approach, by contrast, does explain computational processes causally, guaranteeing a reliable connection between explanatory levels. Milkowski's view is therefore, interestingly, that we can see the mechanistic account as a causally constrained version (and thus successor) of the functionalist approach. The former completes the latter by including the causal processes by virtue of which the system performs the task under consideration.

In “Computation and Representation,” the fourth chapter of Milkowski's book, he points out that Jerry Fodor's slogan “no computation without representation” had it backwards. There is no representation without computation. Information processing is a prerequisite of representation, but it is crucial to note that information is not the same as representation. Representation is reducible to neither the source of information in the environment or the input to the information processing. Informational content only becomes representational if it plays the proper function of representation, which is a causal relationship between the system and its environment. The essential features of a proper representational system are its causal ability to detect an error in its own representation and its embeddedness in the control structures of cognitive systems. This requires referral (if any is possible), determining the relevant content of the environment as well as evaluating its epistemic value, meaning misrepresentations should be detectable from inside the system as a discrepancy between predictions and the state of the environment.

In his last chapter, "Limits of Computational Explanation,” Milkowski points to some limits of the computational explanation. The physical implementation of a computational system in an environment lies outside of a computational explanation. Even though the performance of a cognitive system also depends on its physical properties, they cannot all be understood purely as computations. Hence, it would be mistaken to defend that computational explanations are strict mechanistic explanations of cognition or that cognition is identical to computation. While the core of the book is to defend a mechanistic approach to computational explanations of cognition, it also made clear that implementation is partly identified in non-computational terms and that we need to appeal to representation in order to explain how computational mechanisms are connected to the world. Milkowski therefore ends his book with a plea for explanatory pluralism, which involves two claims. The first is that computation is not the only way to explain cognitive systems because it involves non-computational elements such as physical structures, environments and real-time interaction. The second thesis questions whether all explanatory methodologies need to be replaced with a single one, which at this point seems premature to say the least.

Discussion

Milkowski addresses the notion of a computational mind in a concise and yet remarkably comprehensive manner. However, we do have to note that he is at times subjective to repetition or superfluous clarification when other sections have a cascade of strenuous terminology without much elaboration. Above all, we appreciate the pluralistic flavor of this work. Philosophers of science have far too often expressed the need to capture or find essential features of a unified science. When looking at the current philosophy of explanation, for example, it is hard to be unsympathetic towards pluralist views. Multiple approaches to explanation are founded upon the belief that specific scientific branches have other explanatory subjects, methodologies or goals. Even when looking into one specific phenomenon, it is now a general idea that it cannot be fully explained by a single theory or fully investigated using a single approach. As a consequence, philosophical treatments that do try to present overarching models of explanation are often refuted for missing this exact goal. Milkowski gives a compelling and scientifically solid argument for the idea that computation can be described.

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in various ways. Moreover, he admits that computation cannot explain cognition on its own. Consequently, the scope and success of a computational explanation varies in certain contexts. It is nonetheless a shame that not all notions are examined in this same manner. While he emphasizes the pluralistic nature of computation and computational explanation, when it comes to information, for example, he states that the world contains of "structural-information [...] before it gets into the cognitive system" (156). He does not give further argumentation of what this means. Notions such as information and mechanisms, as we will see later, are also subject to various and dissimilar interpretations throughout philosophical literature. While we agree that a further explication of different views of these concept would probably lead to a further superfluous clarification, it sometimes remains unclear how we should interpret it with when faced with the extensive literature and other debates.

Though never made explicit, there is much to savour for any radical constructivist. Any scientific or philosophical theory that involves cognition (involving knowledge and/or representation) carries the weight of addressing the relationship between the subject and object of knowledge (Stewart 2001). Much of the confusion that Milkowski attempts to untangle comes from approaching cognition with the need to incorporate a realist notion of knowledge. This is especially clear in the terminology of representation (and Milkowski’s demand for misrepresentation). This bears some traditional baggage of an independent reality that is being represented, as is evidenced by the classical simulation model of cognition. However, Milkowski conceives of representations without a need for the discovery and representation of any objective reality. Instead, representations mark themselves out by the functional role they play for the system, which could equally be put as having “viable procedures” (Glasersfeld 2001). In this, his account approximates Humberto Maturana’s (2002) notion of knowledge as operational coherence, rather than a semantic theory of referents, which he rejects. This is also clear in Milkowski’s requirement for a representational system to be capable of misrepresentation, which should only be described as a discrepancy detected inside the system. There does not need to be a match with reality, but it does need to be noticeable whether or not an anticipation (or hypothesis) fits the experiential world (Glasersfeld 1984).

However, as Milkowski successfully notes, to consider a cognitive system as viable in its activities requires some description of the way it is embedded in its environment or, put differently, how it is structurally coupled to its medium (Maturana 2002). Cognitive systems need to be at least partially open, for otherwise, says Milkowski, they would not be cognitive. Cognitive systems are operationally closed, but they are materially and energetically open to an environment (Hall & Nousala 2010) with which their behavior is structurally coupled (Maturana 1974). The success of a system’s activities depends on the way the world is. Completely closed physical systems would have no need for representation of the external world. There is an appropriate domain of description to talk about the correspondence between effective behavior and the structure of the medium in which it takes place as long as one does not confuse this domain of description with the domain of structural (biological) mechanisms that operate to produce behavior (Winograd & Flores 1990). Furthermore, Milkowski stresses the interlocking behaviors of the physical components of a cognitive system, in line with Maturana’s structure-determined system (Winograd & Flores 1990), though Maturana calls this an abstraction rather than an ontological assumption or explanatory principle (Maturana 2002).

Furthermore, it is clear that explanation receives considerable attention in this book. Among others, explaining and predicting phenomena are the most important goals of science. In radical constructivism there is a tendency to focus, similarly to instrumentalisists, on predictions and treat explanations as less important. Instrumentalism holds that theoretical models are mere tools for useful predictions, rather than explicating explanatory relations in an external world. This, however, does not necessarily mean that Milkowski does not provide a book that it is interesting for readers who think along these lines. Firstly, Milkowski sees a strong link between explanation and prediction. Although the main focus remains on explanation, Milkowski argues that prediction is a necessary test in order to see whether the explanatory model is general enough or not. Secondly, not all models of explanation are burdened with metaphysical beliefs about the external world. Milkowski uses two core concepts to defend the notion that his mechanistic approach is more successful than the functionalist approach, namely causation and mechanisms. These terms can certainly be linked with metaphysical debates, but Milkowski does not make any direct claims about the ontology of an external world. As we will show in the next paragraphs, there is no consensus in other literature at all, and constructivist approaches to these concepts are not problematic.

First of all, there are debates between realist and, among others, constructivist approaches to causation. For example, causal realism can be characterized as the view that causation exists in an external reality. The opposing view, causal constructivism, states that the existence of causal relations depends on the presence of minds, speakers or observers. Without going into detail, we can refer to Jon Williamson (2007) and his convenience doctrine. He argues that it is convenient to represent the world in terms of cause and effect, since it enables us to make successful inferences and make correct predictions, correct diagnoses and successful strategic decisions. It is because thinking in terms of effects is convenient, not because there is something physical corresponding to the cause of human experience, that humans tend to think in causal terms. While this doctrine may seem constructivist at first sight, it is rather said that convenience is a sufficient explanation for the existence of causal beliefs. We do not have to refer to the existence of an external world in order to defend the usefulness of causal beliefs. Nevertheless, it remains the case that the use of causation, certainly in Milkowski’s pluralistic view, does not have to be at odds with constructivist views.

Secondly, looking into the metaphysical discussion on mechanism, it is useful to refer to Wesley Salmon’s (1984) distinction between two grand traditions of scientific explanation, which he calls the epistemic conception and ontic conception. The former explains a phenomenon by showing how it fits into a causal network, the latter shows that it fits into a nomic network. Nomic traditions, with Hempel’s covering law model as...
the main example, see logical necessity and nomic expectability as core features of scientific explanation. These explanations are seen as arguments. Scientific explanation, according to the ontic conceptions, consists of exhibiting the phenomenon to be explained as occupying a specific place in the patterns and regularities that structure the world. The orthodox view is that mechanistic conceptions assimilate with the ontic approach. On the one hand it omits all non-ontic entities—such as diagrams, names, equations, etc.—to play a distinctive role in the explanatory framework. On the other hand, mechanistic explanations are often presented as demonstrating the physical or causal relationship between the explanans and the explanandum. In this sense, explanations are not argument as in the nomic approach, but the explanans is a mechanism and the explanandum is the phenomenon causally produced. Its component parts, operations and organization are themselves what do the explaining, precisely in the sense of being the explanans. This is a limited view however. First of all, philosophers do not agree on the specific status of mechanisms and mechanistic explanations. Carl Craver (2007), an important author in the mechanistic tradition and a clear inspiration for Milkowski’s account, states that mechanistic explanation is ontic and shows how the phenomenon fits in the causal structure of the world. Cory Wright and William Bechtel (2007), equally important voices in the mechanistic debate, defend an epistemic view, stating that explanation is an essential human activity, with the goal of understanding the phenomenon. Wright and Bechtel are, consequently, interested in mental models and our knowledge of mechanisms. Hence, the concrete nature and scope of a mechanistic explanation is open for discussion. Secondly, even in a strong ontic view, causal relations lie at the foundations of the patterns and regularities, and we already mentioned that causality can be approached in different ways. Nothing stops us from defending a second convenience thesis. Milkowski argues that mechanisms are more convenient in order to explain certain cognitive processes. Similarly to causation, we can treat mechanistic frameworks as a useful ordering and organization of a world constituted by our experience. Without explicating specific ontological statements, Milkowski uses the core idea that cognition is about transforming a stream of input information into a stream of information in the output. Heinz von Foerster has stated that “[t]he environment contains no information. The environment is as it is” (2003: 189). As a matter of fact, von Foerster also presented an approach to computation (1984) where cognitive processes are seen as a never ending recursive process of computation. Nevertheless, there are also dissimilar approaches to the notion of information (Adriaans 2013). Our argument is that Milkowski does not start working from or towards a certain ontological point of view and, as mentioned above, the road is open to reading his proposal with different philosophical backgrounds. Whether the argumentation will be equally fruitful, is question-begging. Even with ontological agnostic views on causation and mechanisms, the turn towards mechanism in order to provide better explanations will be less rewarding for the radical constructivist. In some cases Milkowski will, perhaps, get a better grip on the scientific view on certain phenomena. But whether the functionalist approach will be left behind as easily is question-raising.

To conclude, given the already large attention and literature on computational approaches in cognitive science, we can state any doubt that it succeeds in being an interesting contribution. The accurate and comprehensive presentation of both scientific and philosophical insights makes it a recommendation for anyone interested in computation and/or in cognitive science. Whether or not you are persuaded by Milkowski’s argumentation for a mechanistic account, this book kindles thought about several intriguing questions.

References


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