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.

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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-book 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, Tanguauy & 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 phenomonon, 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 practioners; 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 inherant 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.

« 5 » Kynigos claims that the democratization of designing for c-books is a "neutral" research process, where "social creativity" will throw up an optimal version of c-books. While certain criteria guiding the creative process were agreed within the CoI, there ap-

pears to be a disinclination to examine power relations within the project. However, trusting in the constructionist overarching theory, 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.

Dolores Corcoran is a retired lecturer in mathematics education at St Patrick's College, Dublin City University, where she currently teaches an elective course: *Investigating Mathematics for Teaching*. Dolores was a teacher in primary schools for much of her career and her research interests are focused on mathematics teaching practices and mathematics teacher development. She has researched and theorised *lesson study* for this purpose. Dolores holds a PhD from the University of Cambridge (2008).

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.

« 1 » 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 fur-

ther development of fine-grained theory to orchestrate and to study such processes.

« 2 » 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 an argument that expressive digital media are "living" artifacts, that they evolve and that they, in turn, change the ways in which humans express meanings and the ways in which these meanings can become visible to others.

The c-book as object and as mediation

« 3 » Brennan 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?

« 4 » 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

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