Discussion: Creating a New World – Teachers' Work in Innovative Educational Environments

Yifat Ben-David Kolikant

1 Introduction

In this essay I discuss two chapters in this volume: (1) *Issues of teaching in a new technology-rich environment: Investigating the case of New Brunswick (Canada) school makerspaces*, by Viktor Freiman, and (2) *The influence of teacher's orchestration through the SAGLET system on students' conceptual learning—the case of a geometry lesson*, by Prusak, Swidan, and Schwarz.

The chapters share important characteristics. Both chapters describe teachers' work in innovative educational environments, aiming at, as Freiman puts it, "provid[ing] non-traditional learning opportunities for the students" (ibid.). Traditional schooling is characterized by information-focused agenda and teacher-centered practices (Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014). Compared to those, both novel environments (a) are student-centered, (b) aim at nurturing twenty-first century skills, such as problem solving, creativity, sharing, and collaboration (Nir et al., 2016; OECD, 2018; Pellegrino & Hilton, 2012) and (c) are technology rich. Freiman's chapter revolves around makerspace environments in which students can design, experiment, build and invent while learning about STEAM (science, technology, engineering, arts, and mathematics). Students engage in a multitude of projects, during which they explore various technologies, create new things of all kinds, and share their products/designs with others. Prusak, Swidan, and Schwarz describe an educational environment in which students collaboratively solve problems in Geometry using a Dynamic Geometry Environment, GeoGebra, that allows them to 'drag' on-screen objects and produce a variety of diagrams, what can help them to examine conjectures and visualize proofs.

In this chapter I elaborate on the crosscutting themes in these chapters. First, I discuss the fruitful relationship between research and practice that both projects

Y. Ben-David Kolikant (✉)
Seymour Fox School of Education, Hebrew University of Jerusalem, Jerusalem, Israel
e-mail: yifat.kolikant@mail.huji.ac.il

Y. Ben-David Kolikant et al. (eds.), *STEM Teachers and Teaching in the Digital Era*, https://doi.org/10.1007/978-3-030-29396-3_17

demonstrate. Then I discuss the innovative nature of the pedagogies described in these chapters. I elaborate on the important role technology plays in facilitating transformative change, in sustaining a different classroom learning culture. Then I discuss the new roles of the teachers as portrayed in these chapters, especially what it means to have “teachers as guides,” and what knowledge and dispositions are involved when teachers aim at maximizing their students’ learning.

2 A Fruitful, Reciprocal Relationship Between Research and Practice

In each of the chapters the described educational environments are inspired by research and theory. The makerspace is grounded in the constructionist philosophy (Harel & Papert, 1991). The environment described by Prusak, Swidan, and Schwarz is grounded in the field of computer-supported collaborative learning (CSCL) (e.g., Roschelle & Teasley, 1995) and argumentation (Baker, 2003). Furthermore, the SAGLET software, that the teachers use, is an outcome of a collaborative research effort of educational researchers and computer scientists (Schwarz, Prusak, Swidan, Livny, & Gal, 2018).

The relationship between research and practice is reciprocal as both chapters shed light on an important topic: teachers’ functioning in such innovative, student-centered environment and their professional growth. What roles do they assume? What practices, knowledge, and dispositions are developed in that process? And, what impact do these teachers have on students’ learning? In both environments, the teachers have to learn to guide the students who often work within multiple tasks, what adds to the complexity of the milieu. This new reality requires teachers to develop different instructional practices in order to maximize students’ learning. The teachers in the study by Prusak, Swidan, and Schwarz use SAGLET, to monitor and orchestrate multiple student groups engaged in parallel on a learning task. The software recognizes critical moments within the groups that are interacting and present this information to the teacher visually. Yet, it is the teacher’s decision as to how to interfere productively in the group work, if at all. The teachers in the study by Freiman needed to support multiple students who work on their own, different projects, often encountering situations when they lack the knowledge required for a specific project.

3 Technology as a Facilitator of Innovative Educational Environment

Each of the two chapters demonstrates the important role of technology in transforming students’ learning and its potential to transform the school/classroom learning culture. The environments in both chapters aim at forming what Salomon, Perkins, and Globerson (1991) termed 'a productive human-computer intellectual partnership.' Salomon et al. distinguished between two types of positive effects of technology on human intellectual performance: effect *with* technology, which refers to changes in the performance of students while equipped with a technology (i.e., a program or a tool), for example, the reduced number of spelling mistakes while using a word processor; and the effect *of* technology, which refers to relatively long-lasting residue in students' abilities and dispositions as a result of interaction with a technology, evident even when they are away from it. Both environments build on the effects *with* and *of* technology, in terms of capitalizing on the experience of today's students with technology and the thinking it encourages (Ben-David Kolikant, 2019); both aim at transforming this human-technology interaction to yield productive learning.

Tools are mediational means, namely when we are introduced to a new tool, our sense of its affordances and constraints gradually evolves, and our goals and actions with the tool, as well as our understanding of the context within which we act, are transformed (Wertsch, 1998). This conceptualization suggests that ICTs transforms students and other users' actions and values, namely, what is deemed as good, appropriate, and efficient in this respect (Bolter, 1984; Brown, 2000; Wertsch, 1998).

Specifically, both environments are aimed at encouraging bricolage or tinkering, which can be taken to mean 'trial-and-error,' learning by "poking around, doing this or that and eventually get it right " (Papert, 1996, p. 86). Bricolage is also about "the abilities to find something – an object, tool, document, a piece of code – and to use it to build something you deem important" (Brown, 2000, p. 14). Turkle asserts that computer and Internet technology made bricolage legitimate or even necessary skill. Computer use moves us "in the direction of accepting the postmodern values of opacity, playful experimentation, and navigation of surface as privileged ways of knowing" (Turkle, 1995, p. 267). Similarly, Brown (2000) claims that life with the Internet brought about a shift in what is considered as valid reasoning, from the linear, deductive, abstract style of the book generation, to bricolage.

Both environments build on this capacity of the technology. Prusak, Swidan, and Schwarz believe that "teaching geometry should encourage the adoption of experimental learning methods and implementation of inquiry techniques… an activity that invites the use of **intuition, visualization,** and **trial and error** modes of investigation" (ibid., p. 293 emphasis in original). The dynamic visualization of the DGE [Dynamic Geometry Environments] invites such learning methods. Similar ideas are expressed by Freiman who envisions: "an environment in which students can design, experiment, build and invent while learning about STEAM" (ibid., p. 273).

Modern Information and Communication Technology (ICT) also encourages sharing and collaboration (Bonk, 2009). For example, Bruns (2007) points out the emergence of what he termed 'produsaging' – a new hybrid form of simultaneous production and usage – amidst today's generations of users. The ICT users are thus engaged in collaborative and continuous building and extending of existing content in pursuit of further improvement (e.g., Wikipedia). In both environments students are expected to collaborate and share, to test their ideas in light of critiques and alternative ideas provided by their peers.

Finally, the SAGLET technology described by Prusak, Swidan, and Schwarz is but one example of a fruitful human-computer partnership that enables cognitive efforts otherwise almost impossible. In Prusak et al.'s case it enabled the teachers to guide multiple groups of students who worked on learning tasks. It is as if the teacher and the computer co-participated in all groups' discussions simultaneously—the computer identified situations that require intervention and the teacher decided how to interfere, if at all.

Obviously, not all the interactions with technology are productive (Ben-David Kolikant, 2012; Selwyn, 2017), and obviously, not all collaborative learning situations are productive (see, for example, Barron, 2003). Our actions (with tools) result from dealing with multiple, often-conflicting goals, some of which are associated with our experience with the tool and the context of its use (as well as our history in general), some with power and authority, (for example, when students' are asked by the teachers to solve a calculation exercise without using a calculator, and using a calculator means cheating), and some with a combination of these factors (Wertsch, 1998). Students can be dragged into endless "hands-on minds-off" trial and error, whereas educators aspire for a growth in students' conceptual understanding as well as the development of learning skills and knowledge. This is when the teacher's guidance becomes an important asset.

4 Teachers as Guides and Facilitators

Teaching is about maximizing students' learning. Teachers have a unique knowledge, termed by Shulman (1986, 1987) pedagogical content knowledge (PCK), that enable them to maximize their students' learning. In traditional schooling, characterized by information-focused agenda and teacher-centered practices, the pursuit of PCK revolves around the question as to how to best explain to students a certain piece of knowledge (Resnick, 2002). This is evident, for example, in Shulman's explanation that PCK includes "the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others." (Shulman, 1986, p. 9).

The environments described in the two chapters are student-centered. In both, teachers' roles had to shift, using the words of Prusak, Swidan, and Schwarz, "from lecturing and telling, to listening, observing, facilitating, and guiding" (ibid. p. 293). Teachers in such environment need to pursue different ways to maximize their students' learning. What characterizes their unique knowledge? The two chapters shed light on this timely issue.

First, teaching in these environments involves multi-tasking. Furthermore, these environments are characterized by great diversity—the teachers in both studies orchestrate multiple groups of students who sometimes work on different tasks, at different pace, encountering various social, cognitive, and metacognitive difficulties. In order to best support their students, the teachers have to adopt flexible (or resilient) approach towards the curriculum, let alone a personalized approach to it, which adds to the diversity that the multi-tasking teachers need to handle. Expert teachers have always been characterized by flexibility and the ability to recognize learning opportunities (Berliner, 2001, 2004; Tsui, 2009), however these novel environments require these characteristics amidst multiple personalized curricula.

Second, as prominent in the makerspace environments, these educational situations often involve the need to pursue new knowledge that the teachers did not master. In fact, learner-centered environments often require an interdisciplinary approach to the problem or task at hand. Teachers need to remain confident in such situations, to learn to live at peace with the fragility of their own knowledge and work productively even if required knowledge is distributed—between themselves, their students, and the environment (see also Kapon's discussion in this volume), and to guide students effectively in such situations. The distributed nature of knowledge is also evident in the work of teachers in SAGLET study. SAGLET, as well as other (artificial-intelligence based) systems, are aimed at distributing the cognitive load between the technology and the users. In the case of SAGLET, the orchestration is distributed between the teacher and the technology. Yet, this requires the teachers to adjust to this new context and capitalize on it; for maximizing students' learning, for example, they need to learn how to best intervene in the conversation where their presence so far was invisible to the students.

Third, the teachers have to generate and sustain a learning culture different from that of the traditional schooling. Freiman noticed that all the teachers he observed and interviewed have developed, as a result of their experience, an 'innovator's mindset'; that they focus on how "to empower learning, unleash talent and foster culture of creativity" (ibid., p. 273). While both environments capitalize on the bricolage that interaction with technology encourages, in both chapters the authors are aware of the various pitfalls, such as the tendency to be engaged in a "minds-off, hand-on" activity, and being satisfied when getting things to "work" (Ben-David Kolikant, 2011). Such concern is raised by Prusak, Swidan, and Schwarz, who aim at assisting the teacher in leading "shifts in the discourse, ensuring that it is conceptually focused and reflective" (p. 293). Freiman quotes Gilbert to express a similar concern: "the real educational value, in terms of productivity, consists in producing ideas: "expressing them, playing with them, testing them, trying them out in different combinations" (Gilbert, 2017, p. 94)" (ibid., p. 273). Groups also often fail due to fruitless interactions between members (e.g., Barron, 2003).

In both chapters, pursuing ways to maximize students' leaning take the form of sustaining productive collaborative learning culture. Freiman reports that the teachers he observed aim at "establishing a supportive, encouraging, caring, and risk-free learning environment for all students. Their approach is essentially inclusive, while targeting each student's higher potential" (ibid. p. 273). These teachers knew their students, in order not only to maximize each student learning, but also to build a collaborative culture where "students not only work together but also help each other based on everyone's unique forces" (ibid.). Thus, these teachers viewed their students as potential resources for their peers and themselves, as designers of fruitful social interaction between the students.

In conclusion, the knowledge teachers have to develop involves the ability to multi-task, to address diversity, and to utilize diversity of learning resources, the ability to support students in situations in which the knowledge required is distributed among the teachers, the students, and the technology. This knowledge for the twenty-first century teaching involves design of social interaction and the implementation of social practices in order to sustain a culture of fruitful collaboration and creative knowledge creation.

The notion of PCK was coined at time when content knowledge was rather stable and teachers were assumed to master it. Teachers' growing experience was expected to contribute to their PCK, their ability to make certain pieces of knowledge comprehensible to the students (Liberman, Ben-David Kolikant, & Beeri, 2012). As schools adjust to the twenty-first century demands, learning environments such as described in these two chapters—student-centered, collaborative, and focused on knowledge creation—will become prevalent. Knowledge in these environment is no longer stable. It is dynamic and moreover, it is distributed between the various elements and actors within the environment: teachers, students, and tools. Teachers' PCK can and should support their abilities to maximize learning in such environments. For example, Freiman's teachers used their PCK to identify the strengths of their students and to design the social interaction so that the students will serve as resources for the group. However, the nature of PCK expands in order to support teachers' new roles. For example, teachers were always expected to be flexible and adaptive, but the multi-tasking, the diversity inherent in these environments, and the need to effectively guide students amidst distributed, often cross-disciplinary (content) knowledge, paint flexibility and adaptiveness in new colours. Finally, the relation between teachers' PCK and the content knowledge requires further examinations confronted with the reality of distributed knowledge.

References

Baker, M. (2003). Computer-mediated argumentative interactions for the co-elaboration of scientific notions. In J. Andriessen, M. Baker, & D. Suthers (Eds.), *Arguing to learn, confronting cognitions in computer-supported collaborative learning environments* (pp. 47–70). Utrecht, The Netherlands: Kluwer Academic Publishers.

Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences, 12*(3), 307–359.

Ben-David Kolikant, Y. (2011). Computer science education as a cultural encounter: A socio-cultural framework for articulating teaching difficulties. *Instructional Science, 39*(4), 543–559.

Ben-David Kolikant, Y. (2012). Using ICT for school purposes: Is there a student-school disconnect? *Computers & Education, 59*(3), 907–914.

Ben-David Kolikant, Y. (2019). Adapting school to the twenty-first century: Educators' perspectives. *Technology, Pedagogy and Education, 28*(3), 287–299.

Berliner, D. C. (2001). Learning about and learning from expert teachers. *International Journal of Educational Research, 35*(5), 463–482.

Berliner, D. C. (2004). Describing the behavior and documenting the accomplishments of expert teachers. *Bulletin of Science, Technology & Society, 24*(3), 200–212.

Bolter, J. D. (1984). *Turing's man: Western culture in the computer age*. Chapel Hill, NC: University of North Carolina.

Bonk, C. J. (2009). *The world is open: How web technology is revolutionizing education*. New York, NY: Wiley.

Brown, J. S. (2000). Growing up: Digital: How the web changes work, education, and the ways people learn. *Change: The Magazine of Higher Learning, 32*(2), 11–20.

Bruns, A. (2007). Produsage: Towards a broader framework for user-led content creation. In *Creativity and cognition: Proceedings of the 6th ACM SIGCHI conference on creativity & cognition* (pp. 13–15). ACM.

Freiman, V. (2019). Issues of teaching in a new technology-rich environment: Investigating the case of New Brunswick (Canada) school makerspaces. In Y. B.-D Kolikant, D. Martinovic, & M. Milner-Bolotin, (Eds.), *STEM teachers and teaching in the digital era* (pp. 273–292). Cham: Springer.

Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Gebhardt, E. (2014). *Preparing for life in a digital age.* The IEA international computer and information literacy study international report. Australia. Retrieved from https://link.springer.com/content/pdf/10.1007/978-3-319-14222-7.pdf

Gilbert, J. (2017). Educational makerspaces: Disruptive, educative or neither? *New Zealand Journal of Teachers' Work, 14*(2), 80–98.

Harel, I. E., & Papert, S. E. (1991). *Constructionism*. New York, NY: Ablex Publishing.

Liberman, N., Kolikant, Y. B. D., & Beeri, C. (2012). "Regressed experts" as a new state in teachers' professional development: Lessons from computer science teachers' adjustments to substantial changes in the curriculum. *Computer Science Education, 22*(3), 257–283.

Nir, A., Ben-David, A., Ben-David, A., Bogler, R., Bogler, R., & Zohar, A. (2016). School autonomy and 21st century skills in the Israeli educational system: Discrepancies between the declarative and operational levels. *International Journal of Educational Management, 30*(7), 1231–1246.

OECD. (2018). *Organisation for economic co-operation and development*. Directorate for Education and Skills. The future of education and skills: Education 2030. Partnership for 21CS.

Papert, S. (1996). *The connected family: Building the digital generation gap*. Atlanta, GA: Longstreet.

Pellegrino, J. W., & Hilton, M. L. (2012*). Education for life and work: Developing transferable knowledge and skills in the 21st century*. National Research Council. Washington, DC: The National Academies Press.

Prusak, N., Swidan, O., & Shcwartz, B. (2019). The influence of teacher's orchestration through the SAGLET system on students' conceptual learning—The case of a geometry lesson. In Y. B.-D Kolikant, D. Martinovic, & M. Milner-Bolotin, (Eds.), *STEM teachers and teaching in the digital era* (pp. 293–311). Cham: Springer.

Resnick, M. (2002). Rethinking learning in the digital age. In G. Kirkman (Ed.), *The global information technology report: Readiness for the networked world* (pp. 32–27). New York, NY: Oxford University Press.

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer supported collaborative learning* (Vol. 128, pp. 69–97). Berlin, Germany/Heidelberg, Germany: Springer.

Salomon, G., Perkins, D. N., & Globerson, T. (1991). Partners in cognition: Extending human intelligence with intelligent technologies. *Educational Researcher, 20*(3), 2–9.

Schwarz, B. B., Prusak, N., Swidan, O., Livny, A., & Gal, K. (2018). Orchestrating deep learning: A case study in a geometry class. *International Journal of Computer Supported Collaborative Learning, 13*(2), 189–211.

Selwyn, N. (2017). Digital inclusion: Can we transform education through technology? En P. Rivera-Vargas, E. Sánchez, & R. Morales (coords.), *Conocimiento para la equidad social: pensando Chile globalmente* (pp. 103–108). Santiago de Chile, Chile: Colección Políticas Públicas – USACH.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22.

Tsui, A. B. M. (2009). Distinctive qualities of expert teachers. *Teachers and Teaching: Theory and Practice, 15*(4), 421–439.

Turkle, S. (1995). *Life on the screen: Identity in the age of the internet*. New York: Simon & Schuster.

Wertsch, J. (1998). *Mind as action*. New York, NY: Oxford University Press.

Yifat Ben-David Kolikant is an Associate Professor in the Seymor Fox School of Education, Hebrew University of Jerusalem. Her academic work is devoted to theorizing learning, teaching, and schooling in the age of globalization and digitalism, an age characterized by the ubiquity of digital technology, an information explosion, pluralism, and rapid changes. Over the past few years, she has dealt with two core questions: (a) How does digital technology influence schooling and (b) how can effective teaching environments be characterized? In recent years she has been involved in several studies aimed at understanding and enhancing in-service teacher learning under conditions of dramatic curricular and policy changes, and the role that ICT plays and should play in it. Prof. Ben-David Kolikant holds a Ph.D. degree in science teaching from the Weizmann Institute of Science, received in 2002.