Scripted Idea Improvement in a Learning Community Curriculum for Grade 12 Biology

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Abstract: This paper describes a learning community curriculum and corresponding technology environment called *CKBiology*, which was informed by a pedagogical model called *Knowledge Community and Inquiry (KCI)*. Like Knowledge Building (KB), KCI prioritizes epistemic agency, collective cognitive responsibility, and idea improvement. However, in a departure from KB, an important aspect of KCI is the design of curricular *scripts*, which serve to guide the activities of the community towards particular learning goals. In this paper, we present the design of a CKBiology script that includes explicit activities directed at idea-improvement. We then perform an analysis of one CKBiology knowledge base in order to identify the nature of the idea-improvements therein. Our results showed that build-ons tended to be applied to notes containing fewer words and no supporting images. Our results also revealed a substantial proportion of students who "satisficed" their idea improvement activities, highlighting a tension between the values of the learning community (e.g. collective cognitive responsibility) and the merit-based aspects of schooling.

Introduction

What it takes to become a well-informed, virtuous citizen has changed dramatically over the past few decades. Preparing students to become effective citizens means that they should have the knowledge and skills needed to live in a complex and diverse global society, to participate in constructive deliberation, to collaborate with other groups, and to take action to create a more just and compassionate world. These values, along with the affordances of networked technologies, have led to the development of various "learning community" approaches to education (Bielaczyc & Collins, 1999; Brown, 1997; Peters & Slotta, 2010). Learning communities are characterized by "a culture of learning in which all participants are involved in a collective effort of understanding" (Bielaczyc & Collins, 1999, p. 2). Learning communities prioritize students' diverse identities, ideas, perspectives, and experiences, positioning these at the forefront of classroom activities. Students work within different "social planes" (Dillenbourg, 2015) in the pursuit of shared learning goals—contributing ideas as individuals, negotiating and improving upon these ideas in small groups, and expanding these ideas as a whole class. In so doing, students foster a collective epistemology and are given a high degree of agency in regulating their activities.

This paper describes a learning community curriculum for Grade 12 Biology called *CKBiology*, which was grounded in a pedagogical model called *Knowledge Community and Inquiry* (KCI; Slotta & Peters, 2008). Similar to Knowledge Building (KB; Scardamalia & Bereiter, 2006, 2014), students in a KCI classroom work together as a community, contributing ideas to a shared knowledge base, building upon each other's knowledge and nurturing a collective epistemology. However in a departure from KB, an important aspect of KCI is the design of curricular *scripts* (Fischer, Slotta, et al., 2013) which specify the activity sequences, materials, student groupings, and technology elements that serve to guide the inquiry toward particular learning goals (Tissenbaum, Lui, & Slotta, 2012). In alignment with the KBSI theme of *Pervasive Knowledge Building: Multi-Level, Global, Inclusive*, this paper describes how a KCI script can be used to advance the KB principle of *improvable ideas*. Here, we respond to the following three research questions:

1. How can idea improvement be supported within a KCI script?
2. How do notes in the knowledge base vary with respect to the levels of idea improvement they receive?
3. How do students vary in their contributions towards improving other students' ideas?

Theoretical Background

To be successful, computer-supported collaborative learning (CSCL) depends on effective interactions among learners. However, merely assigning students a collaborative task and providing them with communication tools is not sufficient to ensure that their interactions will be productive (Weinberger, Kollar, Dimitriadis, Mäkitalo-Siegl, & Fischer, 2009). Research has shown that learners often struggle to collaborate effectively, to select appropriate strategies, to mutually regulate their behaviour, and to understand the goals or nature of their assigned tasks (Kobbe et al., 2007; Nikol Rummel & Spada, 2007; Weinberger, Stegmann, Fischer, & Mandl, 2007). As well, the more an activity diverges from 'traditional' classroom experiences, the more difficult it may be for students to engage in effective collaborations since they may have little or no experience with the requisite CSCL practices (Fischer, Kollar, Stegmann, & Wecker, 2013).

One approach to supporting collaborative learning is through the use of pedagogical *scripts*. Broadly, a script is "a device by which participants' actions are regulated towards some ideal" (Suthers, 2007 p. 176). A script is a formalism for capturing the pedagogical structure of a learning design (Tissenbaum & Slotta, 2012). It differs from a "lesson plan" in that a lesson plan is typically centered around *teaching* activities, whereas a script is centered around *learners and their interactions* (Dillenbourg, 2004). Furthermore, a script reflects an underlying theoretical model or hypothesis concerning the *mechanisms* by which learning occurs—i.e. how particular types of interactions are supposed to produce the desired learning effects (Dillenbourg, 2002). Similar to a theatrical script, a pedagogical script includes a set of instructions that specifies the pedagogical scenario (i.e. the "play"), the sequence and timing of activities (i.e. the "scenes"), the responsibilities of individuals (i.e. the "actors" and "roles"), and how and when to constrain particular interactions (i.e. the "scriptlets"; Fischer, Kollar, et al., 2013). A script can be considered a specific type of instructional *scaffold* (Quintana et al., 2004), in that it serves to break down a complex learning process into more cognitively manageable pieces and induce interactions that learners would not otherwise engage in without additional support (Tissenbaum & Slotta, 2015; Weinberger et al., 2009).

A major issue in scripting research is concerned with *the flexibility* and *degree of coercion* of a script. In their pioneering contribution to AI and cognitive science research, Schank and Abelson (1977) put forth a theory on scripting that was based on a computational model of *how people understand stories*. Their formulation of scripts was founded upon the assumption that the human mind worked like a computer program—accessing data structures and drawing long sequences of logical conclusions (Schank & Abelson, 1977; Stahl & Pfister, 2007). Attempts to extend Schank and Abelson's theory beyond its original domain of *understanding stories* (i.e. in an effort to explain other types of human behaviour) have shown to be problematic (Stahl & Pfister, 2007). For example, early educational applications of scripting tended to emphasize prescribed, recurrent, predictable, and fixed patterns of student behaviour, which put it at odds with constructivist approaches that prioritized student agency and creative work with ideas (Bereiter et al., 2017). These early educational scripts could be described as having a high *degree of coercion*, meaning that learners were given very little freedom to escape or deviate from the script (Dillenbourg, 2002). Related to *coercion* is the idea of *over-scripting*, which is when interactions are constrained to such a degree that the collaboration feels unnatural and sterile (Dillenbourg, 2002).

Unlike early approaches to educational scripting, more recent work in CSCL has supported the design of flexible scripts that serve as *situated resources* rather than as impenetrable plans for action (Dillenbourg & Jermann, 2007; Stahl & Pfister, 2007). Fischer and Vogel (in Bereiter et al., 2017) address the aspect of flexibility by distinguishing between scripts that are *adaptive* versus *adaptable*. An *adaptive* script is one in which the level of scaffolding is adjusted based on students' actions, such that an appropriate amount of support is provided when and where it is most needed (Diziol, Walker, Rummel, & Koedinger, 2010). On the other hand, an *adaptable* script is one that can be changed directly by those using it, allowing students to act in more self-regulated ways (Fischer & Vogel, in Bereiter et al., 2017). Both *adaptive* and *adaptable* scripts are controlled by real-time decisions that emerge as the script is being enacted.

Knowledge Community and Inquiry

Knowledge Community and Inquiry (KCI) is a learning community model developed in the mid-2000s by Jim Slotta at the University of Toronto (Slotta & Peters, 2008). Inspired by KB pedagogy, KCI and KB are theoretically compatible, however these perspectives are conceptually distinct—each differing with respect to the objectives of the community, the centrality of student-generated ideas, as well as the level of emphasis placed on prescribed learning goals and activity structures (i.e. scripts). KCI provides structural requirements and design principles that allow (1) an epistemological orientation to help students understand the nature of science and learning communities, (2) a knowledge base that is indexed to the targeted science domain, (3) an inquiry script that specifies collective, collaborative and individual activities in which students construct the knowledge base and then use it as a resource for subsequent inquiry, and (4) student outcomes that allow assessment of progress on targeted learning goals. The model guides the design of activity sequences including individual, group (e.g., jigsaw) and whole-class activities (e.g., brainstorm, resource collecting), ensuring that all students progress on the learning goals. These activity scripts are co-designed with the teacher, and are tailored to meet the unique needs of his/her context and students (Slotta & Najafi, 2012). During classroom enactment, the teacher is instrumental in orchestrating the activities and has a clearly-defined role within the script (Madeira, Fong, & Messina, 2012). Rather than merely serving as a "guide on the side," the teacher becomes a "mentor in the centre," participating in the KCI community as an expert collaborator and mentor. KCI curriculum designs are guided by four design principles, each accompanied by a set of epistemological commitments, pedagogical affordances, and technology elements (Slotta, 2014).

Methodology

This project employed a design-based research (DBR) methodology—an approach that has been widely used in the learning sciences to support the creation and development of innovative learning environments through parallel processes of design, evaluation, and theory-building (Brown, 1992; Collins, 1992; Edelson, 2002). In order to support a KCI approach throughout this course, we developed a custom technology environment called *CKBiology*. CKBiology was designed in close collaboration with our co-design teacher and reflects the unique design constraints of her course structure, her students, and her school context. Accordingly, CKBiology is a bespoke technology that was custom tailored to support our KCI script. CKBiology was designed and developed over the course of five design cycles during the 2016-2017 academic year.

In the first part of our analysis, we report on the design narrative from the fourth design cycle—the most comprehensive implementation of CKBiology. In the second part of our analysis, we use a case-study approach to perform an in-depth analysis of one particular lesson from this unit. The lesson we chose to analyze was selected because it received the highest level of completion by all students (i.e. 100%), and also contained a knowledge base with substantial levels of idea improvement.

Research Context and Participants

This research was conducted at a university laboratory school in a large urban area. Activities took place within two contexts: (1) in a traditional science classroom with a "bring your own device" (BYOD) policy, and (2) in a specially-designed Active Learning Classroom, which was constructed by the school with the explicit aim of fostering productive collaborations between students.

A purposeful sampling approach was used to select the teacher participant. Selection was based upon the teacher's prior experience in KCI research as well as her availability to design and implement a KCI curriculum during the 2016-2017 academic year. The students who participated in this study were an incidental sample in that they happened to be those who were assigned to the classes of our co-design teacher. Student participants consisted of two sections of a Grade 12 Biology course (n=29), both taught by the same teacher.

Sources of Data

Sources of data for this study included CKBiology design documents (e.g. co-design meeting minutes, lesson planning documents, software mockups), researcher field notes, as well as student learning artifacts and data logs captured by the CKBiology environment.

Part 1: Scripting Idea Improvement

In this section we respond to our first research question: How can idea improvement be supported within a KCI script? We designed a script for CKBiology that included explicit opportunities for idea improvement. The CKBiology script included two major components: *Lesson activities*, and "*review challenge*" activities. During the CKBiology lesson activities, students worked together as a learning community to co-construct a shared knowledge base, oriented around particular lesson topics. The knowledge base took the form of a concept map, with each node representing a student-generated explanation of a particular term or concept (see Figure 1). Near the end of the unit, students applied the community knowledge base towards solving some 'real-world' inquiry challenges (e.g. medical case studies). In this paper we focus on the *lessons* portion of the script only, as this was where construction and idea improvement of the knowledge base occurred.

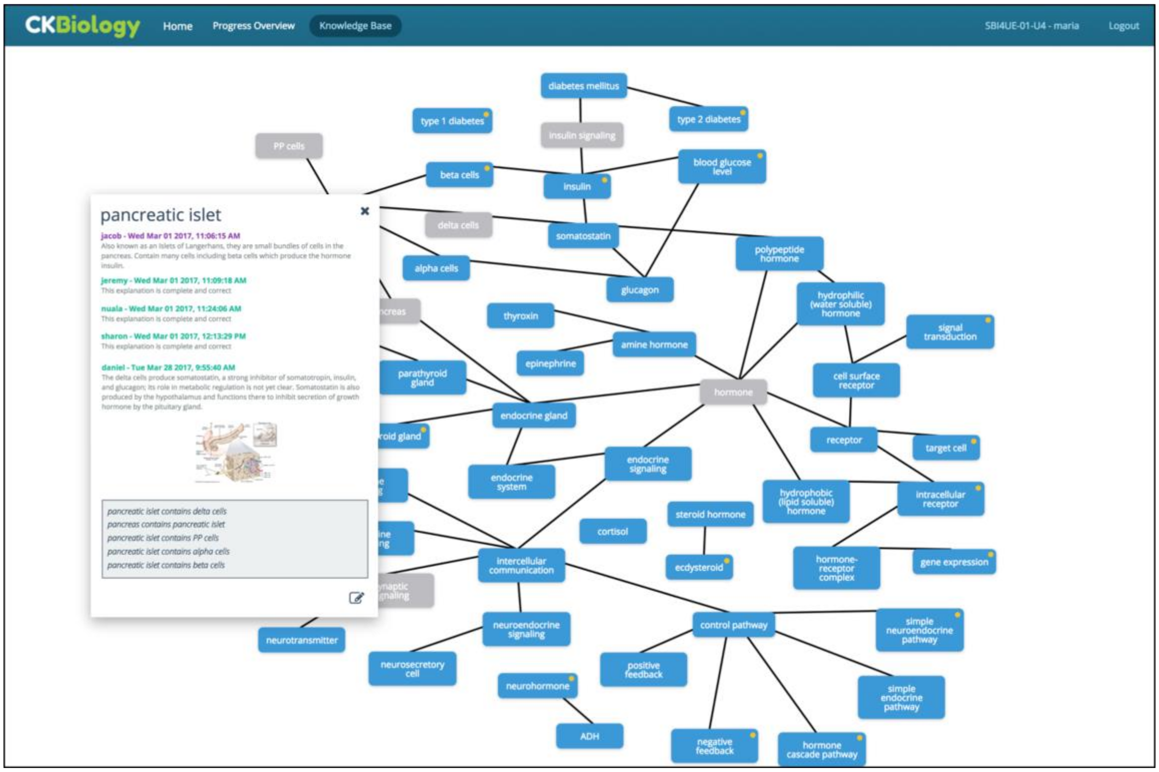

Figure 1. Concept map representation of the community knowledge base in CKBiology. Terms appearing in blue contain completed explanations, while terms appearing in grey have not yet been explained.

The CKBiology lesson activities served to complement traditional classroom lectures, and were performed by students within their regular science classroom using their own devices. In Unit 4, there were eight lesson topics which were taught over fourteen class sessions. Upon logging on to CKBiology, students were presented with the sequence of lessons for the unit, with each lesson activated by the teacher as it was taught (see Figure 2). Upon selecting a lesson to work on, students were assigned three different types of tasks. The first type of task was to *explain terms or concepts* related to that day's lesson. The list of terms associated with a given lesson was established in advance by the co-design team based on the Ontario curriculum expectations, with terms divvied up evenly among all students in the class. Students' explanations for their assigned terms were contributed to the community knowledge base in the form of text-based notes with optional images. On average, students were assigned four or five explanations (i.e. terms or concepts) per lesson throughout Unit 4. The second type of task was to *identify relationships* between terms or concepts in the knowledge base. Within the CKBiology interface, students were presented with two terms separated by a drop-down list of relationship types. In this case, there was actually a 'correct' relationship between each pair of terms, established in advance by the co-design team and programmed into the software. If a student chose the correct relationship, a line would appear connecting the two terms in the knowledge base. The relationship would also appear as a sentence within each note involved in the relationship. For example, the sentence "chloroplast *contains* lumen" would appear in both the "chloroplast" note and the "lumen" note. In CKBiology, students were assigned an average of five relationships per lesson throughout Unit 4.

The third and final task was directed at idea improvement. Here, students were asked to peer review, or "*vet*," explanations that were submitted by other students in the community. Notes were distributed to non-authoring students such that each term received a minimum number of vets (i.e. 6-7 per term). First, students were presented with an anonymized note followed by the prompt: "Is this explanation *complete* and *correct*?" If the student responded "yes," then that student's name would be appended to the note along with the statement "This explanation is complete and correct." If the student responded "no," a text box and image uploader would appear beneath the original note, and the student would be asked to contribute a build-on, submitting any new ideas and/or corrected information (see Figure 3). Any additional information entered by the student would be appended to the original note along with the student's name. Subsequent vetting decisions performed on that note would be appended in the same fashion. Within the knowledge base, a yellow dot was used to identify notes that contained new or corrected information as a result of student vetting (see Figure 1). This yellow dot served as a cue to the teacher to take a closer look at these notes and potentially initiate a follow-up discussion to negotiate these ideas as a class.

Figure 2. CKBiology home screen

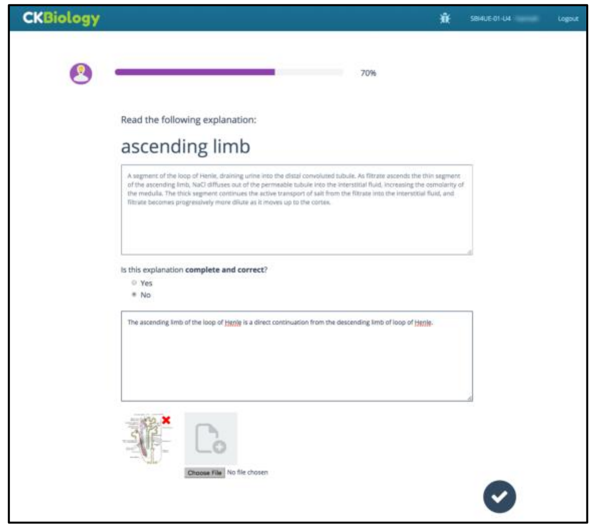

Figure 3. Vetting interface in CKBiology

As students progressed through each of their assigned tasks, a progress bar at the top of their screen would indicate the proportion of work they had completed and the proportion of work that remained. Additionally, on their home screen students could see their individual progress bar for each lesson as well as an overall progress bar for the whole learning community. If a student saw that the progress level of the community was below 100%, they could choose to go ‘above-and-beyond’ their own assigned tasks and make additional contributions to the knowledge base to boost community-level progress. These additional contributions typically took the form of extra vetting tasks, which did not detract from the assigned work of other students. Thus, no single student could dominate the knowledge base by populating an inordinate number of terms and relationships, and every student was still accountable for making their fair share of contributions.

Following the lesson activities, there were two CKBiology *review challenge* activities that were completed by small groups of students within the Active Learning Classroom. The purpose of the review challenge activities was for students to apply their community knowledge towards solving a series of medical case studies—first working as medical specialists, and then working in jigsaw groups (i.e. “medical clinics”), pooling their diverse expertise in order to diagnose a virtual patient with ambiguous symptoms.

Part 2: Analysis of Idea Improvement

Attributes of Improvable Notes

In this section, we respond to our second research question: How do notes in the knowledge base vary with respect to the levels of idea improvement they receive? Within our selected lesson/case, each class section produced a knowledge base containing 31 notes (i.e. terms/concepts). First, we compared the terms containing a “vetting dot” (i.e. indicating that at least one student had improved upon the original explanation) with terms that did not contain a vetting dot. The knowledge bases produced by each class section contained ten terms with vetting dots, however only three of these terms were common between the two classes (i.e. bioenergetics, evaporative loss, and thermoregulation). There were no significant differences in the nature of the terms that contained vetting dots, which represented a mix of concrete nouns (e.g. hypothalamus, endotherm, conformer), abstract concepts (e.g. estivation, acclimatization, bioenergetic strategy), and processes (e.g. thermoregulation, counter-current heat exchange, evaporative loss). As well, terms with and without vetting dots did not differ with respect to the number of relationships (i.e. connections) they formed within the concept map.

Next, we examined the contents of the notes with and without a vetting dot. Overall, notes with a vetting dot contained shorter explanations (M=17.2 words) compared to notes without a vetting dot (M=31.17 words). A student t-test for independent means revealed that this difference was marginal (p=0.063). There were four notes for which the written explanation was accompanied by a supporting image. In all four cases, notes that contained an image did not contain a vetting dot. This finding points to the potential utility of visual evidence in supporting students' explanations (Cober et al., 2015).

Finally, we examined the subset of notes containing a vetting dot in order to identify the types of idea improvements they received. Build-ons to these notes were coded as either "new information," "correction," or "redundant." (The "redundant" category was used in cases where it was evident that the peer-reviewer had not fully read the original explanation and simply provided their own, similar explanation). Overall, 73.9% of build-ons were coded as "new information," 21.7% were coded as "correction," and 4.3% were coded as "redundant."

In a follow-up interview, one piece of feedback we received from the teacher was that that it would be helpful to have two distinct vetting dots—one for when a build-on contained new information, and another for when a build-on contained a counterpoint/correction: "*Because many times I went into the yellow dots and there was no conflict. There was just, like…somebody put half the definition and then the second person put the second half of the definition, and then a third person came in and said 'oh wait a minute, and these are examples of blablabla,' which I thought was great… And then you can take it up in different ways.*"

Students' Contributions to Idea Improvement

In this section of our analysis, we respond to our third research question: How do students vary in their contributions towards improving other students' ideas? Within our script, the task of vetting the knowledge base was fairly coercive (i.e. students would not earn 100% until they had performed a minimum number of peer-reviews). Thus, we were interested in determining the extent to which students may have *satisficed* their peer reviews—for example, by declaring all of the notes they reviewed to be "complete and correct" for the sake of getting through the activity. We classified students as "satisficers" if: (1) *All* of the notes they reviewed were deemed "complete and correct," AND (2) if another student contributed an improvement to a note *after* they had already deemed it to be "complete and correct." Based on these parameters, we found that 13 out of 29 students (i.e. 44.8%) showed evidence of satisficing their peer-reviews.

Next, we compared the "satisficers" with "non-satisficers" in terms of their CKBiology progress scores. There were no significant differences in the first class section, however in the second class section students who were "non-satisficers" earned significantly higher progress scores (M=141.2%) than the "satisficers" (M=105.4%; p=0.04). Acknowledging that 100% represents students' *minimum* required contributions, this finding suggests that the "non-satisficers" were more likely to go 'above-and-beyond' in improving community knowledge compared to the "satisficers," who were more likely to complete only their minimum assigned tasks.

Discussion

In Part 1 we presented the design narrative for CKBiology which included scripted moments of idea improvement in the form of "vetting tasks." Here, notes from the knowledge base were distributed to non-authoring students for peer-review. The design of our script could be considered 'coercive' in that students could not proceed in the lesson until they had completed their current peer-review. Furthermore, students would not earn a progress score of 100% until they had completed a minimum assigned number of peer reviews. As identified in Part 2, the coerciveness of this script may partly explain the substantial number of students (44.8%) who "satisficed" their vetting activities. This finding may have been compounded by the high number of peer-reviews that students were asked to complete (i.e. 13 per student) relative to their other tasks. As well, the progress bar representation in the CKBiology interface did not convey the specific *number* of tasks that remained (i.e. terms, relationships, and vetting), with students' progress expressed as a percentage. We therefore acknowledge three opportunities for future work. The first would be to explore how reducing the coerciveness of the script would influence students' vetting activity (for example, by allowing students to select which terms to review). The second would be to understand how students' vetting behaviour changes when the number of assigned vetting tasks is reduced (or increased). The third would be to design progress indicators that provide students with greater awareness of the number of tasks remaining. If students were made aware that they had, for example, only *five* peer-reviews to complete as opposed to thirteen, perhaps these reviews would be completed with greater care and less satisficing.

The satisficing behaviour we observed may also be partly explained by the nature of our intervention. Because our research ethics protocol disallowed assigning grades for participation, we were forced into a position of focusing on activities that were perceived by students as supplementary to their 'traditional' activities (i.e. lectures, worksheets, and tests). We recognize the general need for epistemological coherence within a learning community approach. Students who are situated within an otherwise lecture and test-based course will have a difficult time identifying with and participating in any "community" elements.

References

Bereiter, C., Cress, U., Fischer, F., Hakkarainen, K., Scardamalia, M., & Vogel, F. (2017). Scripted and Unscripted Aspects of Creative Work With Knowledge. Retrieved from https://repository.isls.org/handle/1/214

Bielaczyc, K., & Collins, A. (1999). Learning communities in classrooms: A reconceptualization of educational practice. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory* (Vol. 2, pp. 269–292). Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Brown, A. L. (1997). Transforming schools into communities of thinking and learning about serious matters. *American Psychologist*, *52*(4), 399–413.

Cober, R. M., Acosta, A., Lui, M., Moher, T., Kuhn, A., Quintana, C., & Slotta, J. D. (2015). The use of visual evidence for planning and argumentation. In *Proceedings of the 11th International Conference on Computer Supported Collaborative Learning* (Vol. 2, pp. 548–551). Gothenburg, Sweden: International Society of the Learning Sciences Inc.

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In P. Kirschner (Ed.), *Three Worlds of CSCL: Can We Support CSCL* (pp. 61–91). Netherlands: Open Universiteit.

Dillenbourg, P. (2004). Framework for integrated learning. *EU Sixth Framework Programme Priority 2, Information Society Technology, Network of Exc.*

Dillenbourg, P. (2015). *Orchestration Graphs: Modeling Scalable Education* (1 edition). Lausanne, Switzerland: EPFL Press.

Dillenbourg, P., & Jermann, P. (2007). Designing Integrative Scripts. In F. Fischer, I. Kollar, H. Mandl, & J. M. Haake (Eds.), *Scripting Computer-Supported Collaborative Learning* (pp. 275–301). New York, NY, USA: Springer US. https://doi.org/10.1007/978-0-387-36949-5_16

Diziol, D., Walker, E., Rummel, N., & Koedinger, K. R. (2010). Using Intelligent Tutor Technology to Implement Adaptive Support for Student Collaboration. *Educational Psychology Review*, *22*(1), 89–102. https://doi.org/10.1007/s10648-009-9116-9

Fischer, F., Kollar, I., Stegmann, K., & Wecker, C. (2013). Toward a Script Theory of Guidance in Computer-Supported Collaborative Learning. *Educational Psychologist*, *48*(1), 56–66. https://doi.org/10.1080/00461520.2012.748005

Fischer, F., Slotta, J. D., Dillenbourg, P., Tchounikine, P., Kollar, I., & Wecker, C. (2013). Scripting and orchestration: recent theoretical advances. In N. Rummel, M. Kapur, M. Nathan, & S. Puntambekar (Eds.), *Proceedings of the Tenth International Conference of Computer-Supported Collaborative Learning* (Vol. 1, pp. 564–571). Madison, WI: International Society of the Learning Sciences Inc.

Kobbe, L., Weinberger, A., Dillenbourg, P., Harrer, A., Hämäläinen, R., Häkkinen, P., & Fischer, F. (2007). Specifying computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning*, *2*(2–3), 211–224.

Madeira, C. A., Fong, C., & Messina, R. (2012). Teacher orchestration of complex inquiry patterns. In J. van Aalst, K. Thompson, M. J. Jacobson, & P. Reimann (Eds.), *Proceedings of the 10th International Conference of the Learning Sciences* (Vol. 2, pp. 68–69). Sydney, Australia: International Society of the Learning Sciences Inc.

Peters, V. L., & Slotta, J. D. (2010). Scaffolding Knowledge Communities in the Classroom: New Opportunities in the Web 2.0 Era. In *Designs for Learning Environments of the Future* (pp. 205–232). Springer, Boston, MA. https://doi.org/10.1007/978-0-387-88279-6_8

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., … Soloway, E. (2004). A Scaffolding Design Framework for Software to Support Science Inquiry. *Journal of the Learning Sciences*, *13*(3), 337–386. https://doi.org/10.1207/s15327809jls1303_4

Rummel, Nikol, & Spada, H. (2007). Can People Learn Computer-Mediated Collaboration by Following A Script? In *Scripting Computer-Supported Collaborative Learning: Cognitive, Computational, and Educational Perspectives* (pp. 39–55). Springer, Boston, MA. https://doi.org/10.1007/978-0-387-36949-5_3

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy and technology. In R. K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 97–118). Cambridge, UK: Cambridge University Press.

Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (2nd ed., pp. 197–212). Cambridge, MA: Cambridge University Press.

Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals and understanding: An inquiry into human knowledge structures*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Slotta, J. D. (2014). *Knowledge Community and Inquiry: New Opportunities for Scripting and Orchestration*. Paper presented at the Network of Associated Programs in the Learning Sciences (NAPLES), Munich.

Slotta, J. D., & Peters, V. (2008). A blended model for knowledge communities: Embedding scaffolded inquiry. In *Proceedings of the 8th international conference on International conference for the learning sciences-Volume 2* (pp. 343–350). International Society of the Learning Sciences.

Stahl, G., & Pfister, H.-R. (2007). Scripting group cognition. In F. Fischer, I. Kollar, H. Mandl, & J. M. Haake (Eds.), *Scripting Computer-Supported Collaborative Learning: Cognitive, Computational, and Educational Perspectives* (pp. 328–335). New York: Springer.

Suthers, D. D. (2007). Roles of computational scripts. In F. Fischer, I. Kollar, H. Mandl, & J. M. Haake (Eds.), *Scripting Computer-Supported Collaborative Learning: Cognitive, Computational, and Educational Perspectives* (pp. 177–187). New York: Springer.

Tissenbaum, M., Lui, M., & Slotta, J. D. (2012). Co-designing collaborative smart classroom curriculum for secondary school science. *Journal of Universal Computer Science*, *18*(3), 327–352.

Tissenbaum, M., & Slotta, J. D. (2012). Scaffolding a knowledge community for high school physics. In *Proceedings of the 10th International Conference of the Learning Sciences* (Vol. 2, pp. 436–440). Sydney, Australia: ISLS Inc.

Tissenbaum, M., & Slotta, J. D. (2015). Scripting and Orchestration of Learning Across Contexts: A Role for Intelligent Agents and Data Mining. In L.-H. Wong, M. Milrad, & M. Specht (Eds.), *Seamless Learning in the Age of Mobile Connectivity* (pp. 223–257). Springer Singapore. https://doi.org/10.1007/978-981-287-113-8_12

Weinberger, A., Kollar, I., Dimitriadis, Y., Mäkitalo-Siegl, K., & Fischer, F. (2009). Computer-supported collaboration scripts: Perpsectives from educational psychology and computer science. In N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, & S. Barnes (Eds.), *Technology-Enhanced Learning: Principles and Products* (pp. 155–173). Springer.

Weinberger, A., Stegmann, K., Fischer, F., & Mandl, H. (2007). Scripting Argumentative Knowledge Construction in Computer-Supported Learning Environments. In *Scripting Computer-Supported Collaborative Learning* (pp. 191–211). Springer, Boston, MA. https://doi.org/10.1007/978-0-387-36949-5_12

Acknowledgments

This work was supported by the Social Sciences and Humanities Research Council of Canada.