Knowledge Integration in the Digital Age: Trajectories, Opportunities and Future Directions

Marcia C. Linn (co-chair), University of California at Berkeley, mclinn@berkeley.edu
Bat-Sheva Eylon (co-chair), Weizmann Institute, bat-sheva.eylon@weizmann.ac.il
Adi Kidron (organizer), University of California at Berkeley, ady.kidron@berkeley.edu
Libby Gerard, University of California at Berkeley, libbygerard@berkeley.edu
Emily Toutkoushian, University of North Carolina at Chapel Hill, toutkous@live.unc.edu
Kihyun "Kelly" Ryoo, University of North Carolina at Chapel Hill, khryoo@email.unc.edu
Kristin Bedell, University of North Carolina at Chapel Hill, kdbedell@live.unc.edu
Amanda Swearingen, University of North Carolina at Chapel Hill, aks11@live.unc.edu
Douglas B. Clark, University of Calgary, douglas.clark@ucalgary.ca
Satyugjit Virk, Methinks Technologies Inc., sat@methinks.io
Jackie Barnes, Children's Museum of Pittsburgh, jacqbarn@gmail.com
Deanne Adams, Vanderbilt University, deanne.adams@gmail.com
Alisa Acosta, University of Toronto, alisa.acosta@utoronto.ca
Jim Slotta, Boston College, slotta@bc.edu
Camillia Matuk, New York University, cmatuk@nyu.edu
Christopher Hovey, New York University, chris.hovey@nyu.edu
Talia Hurwich, New York University, th1425@nyu.edu
Juan Pablo Sarmiento, New York University, jps651@nyu.edu
Jennifer L. Chiu, University of Virginia, jlchiu@virginia.edu
Jim Bywater, University of Virginia, jpb6qx@virginia.edu
James Hong, University of Virginia, jh7ub@virginia.edu
Hava Ben-Horin, University of Haifa, LINKS I-CORE, hava.abramsky@gmail.com
Yael Kali, University of Haifa, LINKS I-CORE, yael.kali@edtech.haifa.ac.il
Ornit Sagy, University of Haifa, LINKS I-CORE, ornit.sagy@gmail.com
Tali Tal, Technion Institute of Technology, rtal@ed.technion.ac.il
Jonathan Osborne (discussant), Stanford University, osbornej@stanford.edu
Dianna Laurillard (discussant), UCL Institute of Education, d.laurillard@ucl.ac.uk

Abstract: Researchers from around the world have shaped knowledge integration (KI), a framework that captures the processes learners use to build on their multiple ideas and refine their understanding. KI emerged 25 years ago from syntheses of experimental, longitudinal, and meta-analytic studies of learning and instruction. Advances in KI have resulted from partnerships that combine expertise in learning, instruction, classroom teaching, assessment, technology, and the disciplines. This structured poster session includes partnerships that have advanced design of instruction, assessment, professional development, learning technologies, and research methodologies. Participants report on new technologies, including games, to strengthen KI; instructional designs that take advantage of collaboration to support KI; and extensions of KI to integrate science with other disciplines. They summarize exciting results and identify promising opportunities for advancing STEM instruction to promote intentional, life-long learners in the digital age.

Introduction

This structured poster session brings together partnerships using the knowledge integration (KI) framework to advance their research programs. Over the past 25 years, KI research has documented how learners grapple with multiple, conflicting, and often confusing, ideas about scientific phenomena and led to the identification of design-principles (Kali, 2006) and learning processes (Linn & Eylon, 2011) that promote coherent understanding (Kali, Linn & Roseman, 2009). KI design principles have been refined in designs of instruction, assessment, professional development, and technologies. For example, the Web-based Inquiry Science Environment (WISE), used in many of the works presented in this session, supports authoring and customization of instruction, logging of student interactions with simulations or virtual experiments, and random assignment of students to conditions within classes (see Study 1, 2, 7, 8).

Researchers studying KI have identified four interrelated reasoning processes that students use to integrate and make sense of their ideas. The posters address ways to use and strengthen all these processes:

- *Elicit ideas*. Prompting students to articulate and explicate their existing ideas (e.g., making predictions or brainstorming initial ideas) ensures that new ideas can be considered alongside pre-existing ones for inspection and refinement (see example in Study 5).
- *Add ideas*. Through carefully designed guided activities and representations (Parnafes & diSessa, 2004) students can encounter new scientific ideas to add and connect to existing repertoire (Study 3, 4, 6, 8).
- *Distinguish ideas*. Learners need support in developing coherent ways to evaluate the scientific ideas they encounter. Designed instructional activities featuring critique, informative data displays, or trade-offs can help students to develop criteria for distinguishing useful, relevant ideas from unproductive and irrelevant ones (Kidron & Kali 2015; see Study 1, 2, 4, 6, 7).
- *Reflect and integrate ideas*. Students reflect on their repertoire of ideas by applying criteria to evidence, making note of contradictions and identifying instances where additional information can help to resolve weaknesses, gaps or inconsistencies in understanding. In doing so, students reformulate both their criteria and their accounts of scientific phenomena (see examples in Study 1,3).

This structured poster session includes partnerships that have advanced design of instruction, assessment, learning technologies, and research methodologies. The studies represented in the posters explore KI in a variety of age levels and contexts: middle schools, high schools, and university courses. Participants report on *new technologies*, including adaptive guidance to support students' use of science practices to strengthen disciplinary explanations (studies 1, 2, 3). Studies report on instructional designs that strengthen *socio-cultural aspects of learning* (studies 4, 5) by supporting collaborative interactions and a culture of interdependence among students. Further innovations extend KI beyond science to guide and assess student reasoning in *complex, multidisciplinary, real-world* challenges (studies 6, 7, 8). Taken together, the use of KI across research programs expands our understanding of learning in the digital age and provides a shared framework for advancing STEM instruction to promote intentional, life-long learners.

The Chairs will set the context of the poster session by discussing how KI is building robust learning sciences findings that have powerful practical implications for education. Each of the eight partnerships will have two-minutes to introduce their poster. Attendees will visit each poster to discuss research findings, the impacts, and research implications. Posters will be clustered around: new technologies, including games, to strengthen KI; instructional designs that improve collaborative learning; and innovations that take advantage of cultural and disciplinary diversity to support KI. Diana Laurillard, London Knowledge Lab (LKL) and Jonathan Osborne, Stanford, will synthesize emergent themes across posters. The session will end with audience discussion.

Study 1. Teacher customization of automated guidance to strengthen revision for knowledge integration

Marcia C. Linn and Libby Gerard

In this study, we combined teacher guidance with automated guidance to strengthen the frequency and quality of student KI essay revision in inquiry science units. The NGSS have shifted the focus of science instruction from recall of factual information to the integration of science practices, disciplinary core ideas, and crosscutting concepts. Revising KI essays aligned with NGSS involves an iterative, recursive process of constructing understanding while revising ideas (Bransford, Brown, & Cocking, 1999; Osborne, 2014). Advanced natural language processing (NLP) techniques, enabled us to design adaptive KI guidance for student written essays embedded in inquiry units to encourage students to revise. Across multiple studies, the adaptive KI guidance proved to be more effective in improving learning than other types of guidance typically assigned in a middle school classroom (Gerard, Matuk, McElhaney & Linn, 2015). Yet, we noticed a troubling pattern: students struggled to use guidance to revise their essays. Across 5 studies, 27% of students on average made no revision; only 42% made productive revisions that integrated or linked relevant pieces of evidence together. The remaining 30% tacked on a disconnected idea to the end of their initial response.

We partnered with a 6th grade teacher implementing the WISE Plate Tectonics unit with her 201 students (53% non-White; 34% receive a free/reduced price lunch) to customize the automated guidance system to promote revision among her students. To establish goals, the system assigned a score for each essay revision. To provide struggling students just in time support, the teacher set alerts to notify her in real-time if a student scored a 2 or lower (out of 5), after their first revision. The teacher set the expectation that all students should achieve a top score through revision. To support them, she required students to check-in with her after they received automated guidance and made a revision, and before they submitted their essay a second time.

Analysis of 37 audio recordings of teacher-student guidance interactions, suggest that the teacher used the automated KI guidance as a starting point to strengthen students' essay revisions. First, the teacher had the student read the guidance they received aloud. Then she probed for elaboration (e.g. You said the blob goes up because it is hot. Well if it is hot, is it more dense or less dense?). If the student needed further assistance, the teacher directed the student back to the model and focused their attention on a particular piece of evidence. After the conversation the teacher guided the student to express how they planned to revise their essay (e.g. You mentioned some great ideas. What are those to include [as you revise])? The teacher's customization increased the number of students who revised their essays (96%) and the quality of their revisions ($N=100$ pairs, $M_{gain(revised-initial)}=.48$ $SD=.81$, $t(99)=5.93$, $p<.001$).

Engaging teachers in customizing an automated guidance system can improve student revision of essays for KI. Customizing encouraged the teacher to take ownership for the revision process, generating criteria for successful essay revision and developing strategies to help students engage in a successful revision process. Future research should explore extending teacher customization beyond the automated guidance and into the use of aggregate analyses of automatically scored student essays to inform customizations that address the class's evolving ideas.

Study 2. Leveraging log data from simulations to understand students' knowledge integration processes

Emily Toutkoushian, Kihyun "Kelly" Ryoo, Kristin Bedell, Marcia C. Linn, and Amanda Swearingen

Simulations can provide students with opportunities to engage in science practices by allowing them to manipulate variables, plan and conduct virtual investigations, and collect and analyze data to deepen their understanding of complex scientific phenomena (NGSS Lead States, 2013). Advances in new technologies enable the automatic collection of massive amounts of data while students are interacting with simulations, including time-stamped logs of students' clicks, variable manipulations, and use of evidence to answer reflection questions (Rupp, Nugent, & Nelson, 2012). Such log data can provide powerful insights into how students engage in science and inform the design of effective automated feedback to help students' learning with simulations (e.g., Gobert et al., 2013). However, interpreting log data so that it is useful for educational purposes can be difficult and needs to be guided by relevant learning theories. KI offers a theoretical framework for how students develop an integrated understanding of scientific phenomena through eliciting initial ideas, adding new ideas, distinguishing among ideas, and sorting ideas into a coherent framework (Linn & Eylon, 2011).

This study explores whether and how log data from simulations can be utilized to delineate the relationships between student actions and the four KI processes. The study involved 148 students from 11 eighth-grade science classrooms at two low-income, linguistically diverse schools. Student pairs completed two simulations focusing on states of matter and chemical reactions at the molecular level during two weeks of web-based inquiry instruction. Both simulations were scaffolded by prediction questions, a data table, and reflection questions. We use cluster analysis to group students based on similarities across variables from the interaction data, data table, and embedded questions and then find the characteristic learning patterns of those clusters of students.Our preliminary findings illustrate how students at different levels in the KI process demonstrated distinctive, characteristic patterns while interacting with simulations. For instance, students who had a low KI score on the reflection questions, indicating that they were mainly "adding" ideas in the simulations, tended to engage in more actions related to procedures (i.e., resetting or saving the simulation) than directly manipulating variables within the simulations (i.e., changing the amount of thermal energy). By contrast, students with the highest score on the reflection questions, indicating that they were "sorting" ideas, had the fewest total actions compared to other students and tended to engage mostly in directly manipulating variables or interacting with the graph displaying the simulation results. These interaction patterns can be leveraged to provide adaptive, automated guidance to help students move between KI levels as they investigate a simulation, This study provides implications for making decisions about the design features and automated guidance for simulations to support students' KI learning processes.

Study 3. Scaffolding KI in a digital game through adaptive self-explanation

Douglas B. Clark, Satyugjit Virk, Jacqueline Barnes, and Deanne Adams

Prompting students to engage in self-explanation can enhance KI by encouraging students to engage in meta-cognitive activities to monitor what they do and do not understand (Chi, Bassok, Lewis, Reimann, & Glaser 1989; Roy & Chi, 2005; Chi & VanLehn, 1991). Such meta-cognitive activity is highly beneficial to KI (Clark & Linn, 2013). Research suggests that self-explanation functionality can effectively support KI in the context of digital games. Research also highlights challenges, however, in balancing and integrating the demands and abstraction of self-explanation functionality with the demands and structure of the game. These challenges are particularly true for games that are, themselves, cognitively more complex. The current study presents an approach that adapts the abstraction of self-explanation prompts based on a player's performance.

The current study was conducted with 210 students in the 7th grade classrooms of two teachers in two different middle schools in the southeastern United States. In the navigation-only condition, players programmed their trajectories without any self-explanation prompts. In the navigation+abstract condition, these navigational challenges are paired with a self-explanation prompt that focuses on abstract connections between the navigational challenges and Newtonian relationships. In the navigation+adaptive condition, the navigational challenges are paired with self-explanation prompts that adaptively increase from low abstraction (in which the prompts focus concretely on navigational moves) to high abstraction (in which the prompts focus more abstractly on the navigational challenges in terms of overarching Newtonian relationships).

The results demonstrate that students in this condition (a) scored significantly higher on the post-test than students whose self-explanation prompts were not adaptively adjusted and were always abstract and (b) scored higher, but not significantly so, than students who did not receive the self-explanation functionality. Analyses of gameplay metrics suggest that trade-offs in terms of progress through the game may explain some aspects of these posttest comparisons. Analyses also demonstrate that both self-explanation conditions significantly outperformed the navigation-only comparison condition on a gameplay metric that suggests deeper model-based thinking and KI. These hypothesized differences parallel the distinctions between model-based reasoning and constraint-based thinking reported by Parnafes and diSessa (2004). Future research should explore extending the adaptive self-explanation functionality beyond the current platform into a broader range of digital platforms targeting KI.

Study 4. Orchestration supports for knowledge integration in a blended learning community curriculum for Grade 12 Biology

Alisa Acosta and Jim Slotta

Our work is grounded in a pedagogical model of learning communities called *Knowledge Community and Inquiry* (KCI; Slotta, 2014), wherein students work as individuals, small groups and a whole class to generate a shared community knowledge base and to use that knowledge base as a resource for subsequent inquiry activities. An important aspect of KCI is the design of curricular *scripts* (Fischer, Kollar, Stegmann, & Wecker, 2013) which specify the activity sequences, materials, student groupings, and technology elements that serve to guide the inquiry toward particular learning goals. *Orchestration* refers to the enactment of the script, binding it to the local context of learners, classrooms, curriculum, and instructor, and giving it concrete form in terms of materials, activities and interactions amongst participants (Tchounikine, 2013).

In collaboration with a high school biology teacher, we co-designed and implemented a KCI curriculum and corresponding technology environment called *CKBiology* within two sections of a Grade 12 Biology course. Students contributed to a shared community knowledge base in three ways: 1) By providing written explanations for various terms or concepts, 2) by identifying relationships between pairs of terms or concepts, and 3) by peer-reviewing explanations that had been written by other students. The concepts were presented in a concept map, with links representing the identified relationships, and concepts with completed explanations appearing in blue, uncompleted explanations in grey, and 'incomplete' or 'incorrect' explanations (as a result of peer review) containing a yellow dot. This knowledge base captured the KI processes of adding and distinguishing ideas, and was projected at the front of the classroom as students were working, serving as an orchestration support for both students and the teacher. This allowed gaps or disagreements in the knowledge base to become visually prominent, leading to impromptu class discussions, negotiations, and improvement. Through these activities, we argue that the teacher led the students to develop collective KI within the overall knowledge base.

The knowledge base then served as a resource for subsequent "review challenge" activities. In the first review challenge activity, students chose an area of specialization (i.e. immunology, endocrinology, nephrology, neurology) and worked within these specialist groups to solve a series of challenge problems. For each student, we generated a recommendation score based on the quantity (i.e. # of explanations written) and quality (i.e. # of negative peer reviews received) of their contributions to the knowledge base for each area of specialization. In the second review challenge activity, students formed jigsaw groups containing one representative from each specialization. Playing the role of medical practitioners, the groups integrated their diverse expertise in order to diagnose a virtual patient with ambiguous symptoms. Students were guided through this activity via a series of questions in the CKBiology platform, which included ordering the appropriate lab tests, negotiating and explaining the reasoning behind their diagnoses, and identifying possible treatment options—thereby integrating the knowledge they had acquired over the course of the unit. The poster will illustrate how KCI builds on KI to strengthen community learning.

Study 5. Cognitive processes and collaborative supports for knowledge integration among youth designing games for science learning

Camillia Matuk, Christopher Hovey, Talia Hurwich, and Juan Pablo Sarmiento

We explore youth's learning through their design of educational science games. Such games are unique learning opportunities because they require designers to integrate diverse areas of knowledge, including experience with games, an understanding of science, knowledge of effective pedagogical strategies, and a facility with the design process (c.f., Khaled et al., 2014). As with other complex, real-world problems, this task is best accomplished by a team of interdependent collaborators with distributed expertise, rather than through the equal roles typically assigned to students in traditional classroom settings. But what roles do learners take on in such situations? What is learned, and by whom? How is that learning supported by, and made visible in the game design process? We investigate these questions through our design and enactment of a youth workshop for designing games for science learning.

Our participants were eleven 7th grade youth from a public middle school in a large urban city in the eastern United States. Up to 4 facilitators were present on any given day, as well as two teachers from the students' school. In our 5-day long elective workshop, we tasked students with creating games to teach players about the measles virus. Their games were intended to accompany the comic book, *Carnival of Contagion* (worldofviruses.unl.edu, Diamond et al., 2012), which touches on the pathology and cultural history of the measles virus, and frames vaccination as a social responsibility. The first four days of the workshop took place at a university-based game studies center. Activities guided students in brainstorming design ideas from their reading of the comic, developing and play-testing prototypes, and refining their designs. On the final day, students exhibited their games and hosted a game jam for their peers at school.

Our workshop was informed by research suggesting that dispositions toward STEM develop best during playful, social interactions in which learners can express their ideas, goals, interests, and curiosities; engage in activities driven by shared purpose; and have opportunities to realize the personal relevance of STEM (e.g., Clegg & Kolodner, 2013). We also draw on principles for encouraging disciplinary engagement (Engle & Conant, 2002. Following these principles, we gave students interdependent roles (science wizard, play engineer, and concept artist) intended to help them express agency in their individual responsibilities, as well as to appreciate their peers' unique contributions to their shared goal (cf. Jiang, Shen & Smith, 2016). We also created end-of-day deliverable to encourage student accomplishment of key milestones in the design process. Finally, we created activities that addressed individual expert responsibilities, as well as ideas that crosscut roles and that addressed science game design (e.g., how to align learner and player mechanics), the design process (e.g., how to move from idea to prototype), and the social aspects necessary for productive collaboration (icebreakers, teambuilders).

Our data include field note observations, audio recordings of design activities, student interviews, facilitator reflections, iterations on students' game design artifacts, and responses to surveys. By drawing illustrative examples from our analyses, we describe how students learned to integrate their understanding of science and games throughout their design process. We document the challenge of facilitating this process given students' diverse starting points in their understanding of science, design, games, and pedagogy. Further we describe how different teams approached their interdependent roles, sometime successfully and sometimes not. The teams illuminate the challenges of building a culture of interdependence among learners who are used to school's traditional power structures.

This work adds to the larger program of research on KI by examining how interdependent collaborative learners make connections among their ideas and the contributions of others concerning science discipline ideas and game design. Future work might explore what aspects of KI are useful in such settings, and which might need to be elaborated or adapted.

Study 6. Extending the knowledge integration rubric to assess interdisciplinary understanding

Adi Kidron and Yael Kali

We expanded the KI rubric (Liu, Lee, Hofstetter, & Linn, 2008) to assess interdisciplinary understanding for undergraduate students studying a semester-long interdisciplinary course. The course was based on the Boundary Breaking for Interdisciplinary Learning (BBIL) model (Kidron & Kali, 2015). We used different learning technologies to design features (e.g., video-recorded lectures, collaborative documents, structured feedback activities) that embodied our BBIL design principles: break boundaries between disciplines with an interdisciplinary curriculum and a cross-cutting theme, and between learners by using a learning community approach (Bielaczyc& Collins, 1999).

We refer to interdisciplinary understanding as a synthesis of ideas, data, information, methods, tools, concepts or theories from two or more disciplines (Boix-Mansilla, 2010). Therefore, to assess interdisciplinary understanding we combined KI (Linn 2006, Linn & Eylon, 2011) and interdisciplinary learning as a pragmatic constructionist view (ILPCV) (Boix-Mansilla, 2010). Both frameworks focus on integration processes to promote cognitive advancement. We created a rubric that enabled us to code the different dimensions of interdisciplinary understanding, as conceptualized in ILPCV, and systematically quantify different idea connections, as practiced in KI. In the context of interdisciplinary understanding, the definition of 'connection' was broadened to include: links between ideas within the same discipline (referred to the rubric as 'disciplinary grounding'); links between ideas from different disciplines (referred to as 'idea connection'); links between disciplinary ideas and the cross-cutting theme (referred to as 'disciplinary analysis through integrative lens'); and links between ideas from several disciplines and the cross-cutting theme (referred to as 'synthesis').

We used the BBIL rubric to diagnose the quality of students' interdisciplinary understanding in two different contexts: within a course and between courses. Our data for assessing interdisciplinary understanding were 1,000-word essays students wrote twice during the interdisciplinary course. The essays asked students to integrate different disciplinary perspectives taught in the course to address a novel question.

In the first case (Kidron & Kali, 2015), we found that students' interdisciplinary understanding improved significantly between the essay they wrote for the mid-course assignment (M=67.2, SD=29.4) and the essay they wrote for the final assignment (M=82.5, SD=22.0) [$t(31)=2.96$, $p<0.01$, $d=0.59$]. In the second case (Kidron & Kali, forthcoming) the rubric enabled us to find a significant difference [$t(45) =1.85$, $p =0.04$] between students of two parallel courses: the quality of the interdisciplinary synthesis was higher for students who learned in an online learning community (M=1.85, SD=1.09) compared with students who learned the same contents individually (M=1.30, SD=0.95).

These findings illustrate the potential of KI to support design for and understanding of interdisciplinary thinking processes. It illustrates a way to analyze student reasoning about complex interdisciplinary problems. By doing so, it bridges traditional boundaries between disciplinary and interdisciplinarity reasoning. In an era that poses complex challenges to humankind (e.g., climate change, mass immigration), bridging these boundaries and developing new ways to assess interdisciplinarity are a key goal to the learning sciences.

Study 7. Using a knowledge integration perspective to explore connections among science, mathematics, and engineering modeling practices

Jennifer L. Chiu, Jim Bywater, and James Hong

National standards in the United States emphasize instruction where students participate in and use science and mathematical practices (e.g., Common Core Standards Initiative, 2010; NGSS Lead States, 2013). Engaging students in disciplinary practices can help students understand the nature and development of mathematical and scientific knowledge, create motivation and interest in learning, and make mathematical and scientific concepts more meaningful (e.g., Osborne, 2014). However, students often hold fragmented and even contradictory ideas across science, math, and engineering contexts and struggle to connect disciplinary ideas and practices to everyday contexts.

This poster explores how a KI perspective (Linn & Eylon, 2011) can be used to promote the practice of modeling across science, mathematics, and engineering (e.g., Weintrop et al., 2016). We examine the similarities in national standards by exploring the mathematical practices, such as *model with mathematics;* science and engineering practices, such as *developing and using models* and *using mathematics and computational thinking;* and engineering design strategies, such as *representing ideas* and *conducting experiments* (Common Core Standards, 2010; Crismond & Adams 2012; NGSS Lead States, 2013). In the context of an engineering design project implemented in a mathematics classroom we explore how KI design principles in WISE help students engage in modeling practices. Students ($n = 44$) from two middle-school geometry classes participated in a project with the goal of designing ice cream cones, which included interactive geometry models as well as hands-on prototype building and testing. Using a variety of data sources (e.g., pre/posttests, embedded assessments, log files, video recordings), we found that computer-based, scaffolded engineering design helped students engage in modeling practices to learn targeted content. We discuss how KI principles supported students to make interdisciplinary connections. This work shows that WISE can be extended to mathematics and engineering to distinguish modeling practices across disciplines, and how integrating those practices to develop targeted conceptual understanding.

Study 8. Elaboration of KI processes in a WISE module in order to support the development of socioscientific reasoning

Hava Ben Horin, Yael Kali, Tali Tal, and Ornit Sagy

Research has shown that instruction based on the KI framework, using WISE, improves the integration and transfer of scientific knowledge among communities of students (Chiu & Linn, 2011; Roseman, Linn & Koppal, 2008). WISE authoring tools enable designers to embed digital scaffolds and epistemological prompts that promote student understanding of the nature of science (Linn, Clark & Slotta, 2002). We design and refine WISE instruction to develop students' socio-scientific reasoning and ability to resolve socio-scientific issues (Sadler, Barab & Scott, 2007). Socio-scientific reasoning includes practices needed for negotiation and resolution of controversial, science-related, socio-scientific issues (SSIs). Socio-scientific reasoning involves (a) recognizing the inherent complexity of SSIs, (b) analyzing SSIs from multiple perspectives, (c) appreciating the need for ongoing inquiry into SSIs, and (d) taking a skeptical stance toward potentially biased information. To develop socio-scientific reasoning, students need to integrate scientific, practical, and contemporary knowledge using epistemic thinking (Romine, Sadler & Kinslow, 2016).

In this research, we expanded the KI opportunities in an existing WISE module that addresses a SSI concerning environmental impacts on asthma (Tate et al., 2008). We added scaffolds to support the integration of scientific, contemporary, and epistemic knowledge. For example, a google map was used as a collective knowledge base (Lui & Slota, 2014), allowing students to continuously add and evaluate evidence about the distribution of irritants. We implemented the changes during three iterations of design based research with four 8th grade classes. Data came from observations, interviews, and assessments. We compared pretest and posttest performance on: (a) students' integrated scientific understanding and (b) their socio-scientific reasoning.

Findings revealed improvement of students' integrated scientific knowledge from pretest to posttest. Refinement of the instruction across iterations appears to improve outcomes. The potential of the KI processes to support students' development of particular aspects of socio-scientific reasoning is reflected in the student responses, student interviews, and class observations. Our poster will discuss the elaboration of how each of the four KI processes strengthened students' socio-scientific reasoning. This research suggests refinements to KI supports for the development of socio-scientific reasoning. Moreover, this research points to ways to strengthen the KI framework to support the process of epistemic knowledge development.

References

Bielaczyc, K., & Collins, A. (1999). Learning communities in classrooms: A reconceptualization of educational practice. In C. M. Reigeluth (Ed.), *Instructional design theories and models* (pp. 269-292). Lawrence Erlbaum Associates.

Boix-Mansilla, V. (2010). Learning to synthesize: The development of interdisciplinary understanding. In R. Frodeman, J. Thompson-Klein, C. Mitcham & J. B. Holbrook (Eds.), *The Oxford Handbook of Interdisciplinarity* (pp. 288-306). Oxford: Oxford University Press.

Bransford, J. D., Brown, A., & Cocking, R. (1999). *How people learn: Mind, brain, experience, and school*. Washington, DC: National Research Council.

Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science, 13*(2), 145–182.

Chi, M. T. H., & VanLehn, K. A. (1991). The content of physics self-explanations. *Journal of the Learning Sciences, 1*(1), 69-105.

Chiu, J. L., & Linn, M. C. (2011). Knowledge integration and WISE engineering. *Journal of Pre-College Engineering Education Research (J-PEER), 1*(1), 2.

Clark, D. B., & Linn, M. C. (2013). The knowledge integration perspective: Connections across research and education. In S. Vosniadou (Ed.), *International handbook of research on conceptual change (2nd Edition)* (pp. 520-538). New York: Routledge.

Clegg, T., & Kolodner, J. (2014). Scientizing and cooking: Helping middle-school learners develop scientific dispositions. *Science Education, 98*(1), 36–63.

Crismond, D. P., & Adams, R. S. (2012). The informed design teaching and learning matrix. *Journal of Engineering Education*, *101*(4), 738-797.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*(4), 399-483.

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.

Gerard, L. F., Matuk, C. F., McElhaney, K. W., & Linn, M. C. (2015). Automated, adaptive guidance for K-12 education. *Educational Research Review*, *15*, 41-58.

Gobert, J. D., Sao Pedro, M., Raziuddin, J., & Baker, R. S. (2013). From log files to assessment metrics: Measuring students' science inquiry skills using educational data mining. *Journal of the Learning Sciences*, *22*(4), 521-563.

Jiang, S., Shen, J., & Smith, B. E. (2016). Integrating science and writing in multimedia science fictions: Investigating student interactions in role-taking. Singapore: Intl. Society of the Learning Sciences.

Khaled, R., Vanden Abeele, V., Van Mechelen, M., & Vasalou, A. (2014, October). Participatory design for serious game design: truth and lies. In *Proceedings of the first ACM SIGCHI annual symposium on Computer-human interaction in play* (pp. 457-460). ACM.

Kidron, A., & Kali, Y. (2015). Boundary breaking for interdisciplinary learning. *Research in Learning Technology, 23*. Retrieved from http://dx.doi.org/10.3402/rlt.v23.26496.

Kidron, A., & Kali, Y. (forthcoming). Online learning communities as a pedagogical approach for promoting interdisciplinary understanding through knowledge integration.

Linn, M. C., Clark, D., & Slotta, J. D. (2003). WISE design for knowledge integration. *Science Ed., 87*, 517–538.

Linn, M. C., & Eylon, B.-S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. New York: Routledge.

Liu, O. L., Lee, H., Hofstetter, C., & Linn, M. C. (2008). Assessing knowledge integration in science: Construct, measures, and evidence. *Educational Assessment, 13*(1), 33-55.

Lui, M., & Slotta, J. D. (2014). Immersive simulations for smart classrooms: Exploring evolutionary concepts in secondary science. *Technology, Pedagogy and Education, 23(1),* 57-80.

National Governors Association Center for Best Practices, Council of Chief State School Officers (2010). *Common Core State Standards for Mathematics*. National Governors Association Center for Best Practices, Council of Chief State School Officers, Washington D.C.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by state*s. Washington, DC: The National Academies Press.

Osborne, J. (2014). Scientific practices and inquiry in the science classroom. In Norman G. Lederman & Sandra K. Abell (Eds.), *Handbook of research on science education*. Abingdon: Routledge.

Parnafes, O., & disessa, A. (2004). Relations between types of reasoning and computational representations. *International Journal of Computers for Mathematical Learning, 9*(3), 251-280.

Romine, W. L., Sadler, T. D., & Kinslow, A. T. (2016). Assessment of scientific literacy: Development and validation of the Quantitative Assessment of Socio-Scientific Reasoning (QuASSR). *Journal of Research in Science Teaching*. doi:10.1002/tea.21368.

Roseman, J. E., Linn, M. C., & Koppal, M. (2008). Characterizing curriculum coherence. In Y. Kali, M.C. Linn, & J.E. Roseman (Eds.), *Designing coherent science education: Implications for curriculum, instruction, and policy* (pp. 13-36). New York: Teachers' College Press.

Roy, M., & Chi, M. T. H. (2005). The self-explanation principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 271-286). NY: Cambridge University Press.

Rupp, A. A., Nugent, R., & Nelson, B. (2012). Evidence-centered design for diagnostic assessment within digital learning environments: Integrating modern psychometrics and educational data mining. *Journal of Educational Data Mining*, *4*(1), 1-10.

Sadler, T.D., Barab, S.A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? *Research in Science Education, 37*, 371 –391.

Salen, K. (2007). Gaming literacies: A game design study in action. *Journal of Educational Multimedia and Hypermedia, 16*(3), 301.

Slotta, J.D. (2014). *Knowledge Community and Inquiry*. Paper presented at the Network of Associated Programs in the Learning Sciences (NAPLES).

Slotta, J. D., & Linn, M. C. (2009). *WISE Science: Web-based inquiry in the classroom*. NY: Teachers College Press.

Tate, E.D., Clark, D., Gallagher, J., & McLaughlin, D. (2008). Designing science instruction for diverse learners. In Y. Kali, M.C. Linn, & J.E. Roseman (Eds.), *Designing coherent science education: Implications for curriculum, instruction, and policy* (pp. 65-93). New York: Teachers' College Press.

Tchounikine, P. (2013). Clarifying design for orchestration: Orchestration and orchestrable technology, scripting and conducting. *Computers & Education*, *69*, 500–503.

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology*, *25*(1), 127-147.