Designing and Promoting Knowledge Building Trajectories through a Collective Journey of Scientific Practice

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Abstract: We examined a knowledge-building environment mediated by Knowledge Forum® (KF), enriched with a collective journey of scientific practice model designed to promote collective knowledge advancement. Thirty Grade-Five students studying *Sink or Float* participated in working as opportunistic groups co-designed and enacted the collective journey of knowledge building. Quantitative analyses show that students improved their contribution to collective knowledge advancement. Qualitative analysis reveals how students engaged in knowledge building using the designed collective journey involving formulating problems, generating, synthesizing, and modifying explanations, collecting evidence, making conclusions, and generating emergent questions for sustained collective knowledge advancement. This study sheds light on how the designed collective journey of scientific practice scaffolded young children to work as scientists and promote collective knowledge advancement.

Introduction

Recent science education reforms have emphasized the need to engage students in authentic, real-world scientific practices (NGSS Lead States, 2013). However, classroom practice on scientific practice often exposes students to pre-structured tasks, such as the tasks based on the final, well-structured versions of scientific models as developed by scientists over the years (Chinn & Malhotra, 2002). Since epistemology of science refers to the view of individuals regarding the nature of knowledge and knowing in science (Chinn & Sandoval, 2018; Greene et al., 2016), sophisticated epistemic understanding of science is regarded as a significant goal of science education (Chinn et al., 2011). Notably, science relates to constructing further explanations of the natural world (Chuy et al., 2010). In traditional science classrooms, however, students are rarely asked to propose explanations independently. Instead, they are simply the recipients of explanations made by their teachers (Weiss et al., 2003).

Creating authentic environments that mirror the practices of the discipline's culture is a long-standing focus of the learning sciences (Danish & Gresalfi, 2018). *Knowledge building*, which is a major research theme in the learning sciences, emphasizes the creation of scientific communities (Scardamalia & Bereiter, 2014). In knowledge-building research, Tao and Zhang (2018) supported students in co-designing a collective research cycle, which involved such activities as asking questions, initiating research, posting on KF, theorizing, conducting deeper research, revising theories, and sharing thoughts with the class. Lin and Chan (2018) also examined how students could build inquiry models by putting forward better ideas after proposing and revising ideas/conjectures. As both models highlight the theory-building nature of science, activating students' agency to co-design a collective journey of scientific practice is considered a promising solution to the challenges.

This study engaged students in co-designing their inquiry using a model depicting a collective knowledge-building journey. Specifically, the collective journey is developed as "Ask questions, establish explanations, synthesize explanations, modify explanations, collect evidence, make conclusions, and propose new questions." While there has been substantial evidence of scientific practice using knowledge building (Chen & Hong, 2016), we sought to examine more closely the *trajectory* that supports collective knowledge advancement. The research questions are: (1) What were the effects of the designed collective journey on students' contribution to collective knowledge advancement? (2) How did students' engagement and reflection on this journey illustrate the trajectory of knowledge building in supporting collective knowledge advancement?

Methods

Participants

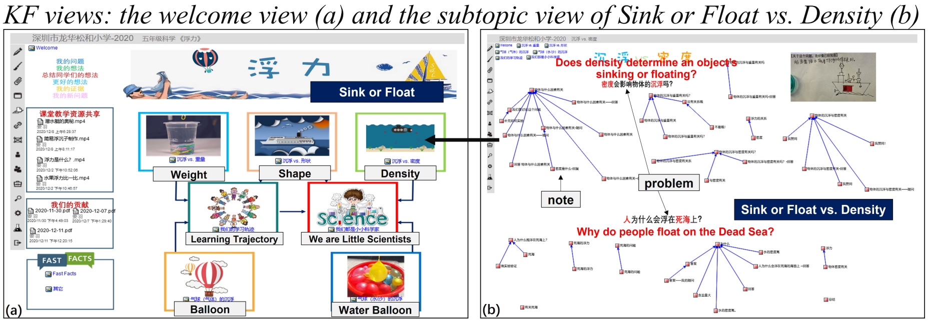
Participants were 30 Grade-Five students from a primary school in Shenzhen, Mainland China, including 11 girls and 19 boys. They were divided into six groups, each with five students. The students had no experience working on KF before this study. The teacher and the researchers worked together as co-investigators.

Design of knowledge building and the collective journey of scientific practice

Working on KF for five sessions, the six student groups explored *Sink or Float* across three phases and conducted different experiments like scientists do in their research process. They were enriched with such KF activities as posting questions, generating theories, co-constructing explanations, revising theories, and collaborating with other groups. While on the collective journey of the scientific practice, they also kept track of their own journeys.

In Phase 1 (Session 1), a discussion was conducted about the widely known famous phenomenon of the heavy Liaoning Ship floating on the sea. Then, this ship was compared with other objects at greater risk of sinking or floating in the water. Based on those authentic problems, students proposed their theories of *Sink or Float* on KF as supported by various scaffolds like “my idea,” “my question,” and “new information.” In Phase 2 (Sessions 2-3), students started by categorizing promising research topics/problems and creating five KF views arising from their questions, including *Sink or Float* vs. *Weight/Shape/Density*, as well as *Sink or Float of Balloons/Water Balloons* (Figure 1a). Following that, students built on the existing ideas to raise new questions for the continued pursuit of inquiry (Figure 1b). Students could enter different views and work on formulating explanations, building on others’ ideas, and proposing new questions for inquiry. In Phase 3 (Sessions 4-5), students synthesized collective ideas/explanations, conducted experiments, and collected evidence, and they also reflected on their knowledge-building journey working as opportunistic groups for the five subtopics.

Figure 1
KF views: the welcome view (a) and the subtopic view of Sink or Float vs. Density (b)



Data source

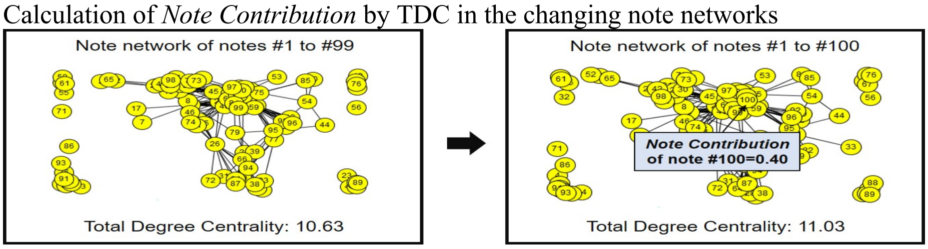
Data sources include KF writings in different views, videos of classroom discourse, and student artifacts.

Results

RQ1: What were the effects of the designed collective journey on students’ contribution to collective knowledge advancement?

Students’ contribution to collective knowledge advancement was assessed by calculating the extent to which the accumulation of their KF notes adds to the Total Degree Centrality (TDC) of the KF database word network exported from KBDeX (Oshima et al., 2012), as shown in Figure 2. This technique has been applied to test the different contributions of students (Oshima et al., 2017). Each student’s collective contribution across the three phases was compared through paired-samples t-tests. Significant differences were found on students’ contribution to collective knowledge advancement between Phase 1 (M = 0.29, SD = 0.44) and Phase 2 (M = 3.16, SD = 2.65), $t(29) = 5.95$, $p < .001$, as well as between Phase 2 and Phase 3 (M = 3.45, SD = 2.72), $t(29) = 3.60$, $p = .001$. These results suggest that students contributed more to the collective knowledge advancement across phases.

Figure 2
Calculation of *Note Contribution* by TDC in the changing note networks



Note. *Note Contribution* refers to the contribution of a note to the numerical increase of the note network’s TDC. For example, the *Note Contribution* of note #100 is 11.03-10.63=0.4.

RQ2: How did students’ engagement and reflection on this journey illustrate the trajectory of knowledge building in supporting collective knowledge advancement?

Theme 1. Proposing diverse ideas concerning authentic problems on KF and conducting exploration for improvable explanations

When engaging in the collective inquiry on the problem of *Sink or Float*, students first put forward the questions and ideas on KF, such as "What is the definition of buoyancy?" They went further to offer explanations and searching for authoritative information online. For instance, regarding the relationship between buoyancy and gravity, student s28 conducted an online search and then used the scaffold of "new information" to propose an explanation that "The only way to describe buoyancy in liquid or gas is from the effect of force. The object of buoyancy is liquid or gas, and gravity is from the nature of force, and the object of force is the earth." This finding was aligned with students' collective journey of scientific inquiry and such practices as asking questions, constructing explanations, and bringing new information for extended collective knowledge.

Theme 2. Identifying promising research problems of *Sink or Float*, synthesizing collective ideas, and proposing possible solutions

Following preliminary KF exploration, students identified the promising research problems before proposing five KF views (subtopics), including *Sink or Float vs. Weight/Shape/Density* and *Sink or Float of Balloons/Water Balloons*. Some questions were raised in different subtopic views, such as "Paper clips are very light, but why do they sink to the bottom?" Experiment designs were proposed to get better explanations based on the synthesized collective ideas and explanations. While classroom scientific practice often involves designing experiments, with this collective journey model and KF affordances, students were engaged in putting together peers' explanations and modifying their explanations (theory) to inform their experimental designs. This is more akin to mature scientific practice. This finding was aligned with the collective journey of students' scientific practice, such as synthesizing and modifying explanations.

Theme 3. Engaging in collaborative problem-solving, re-formulating new questions through experiments, and conducting progressive theory building

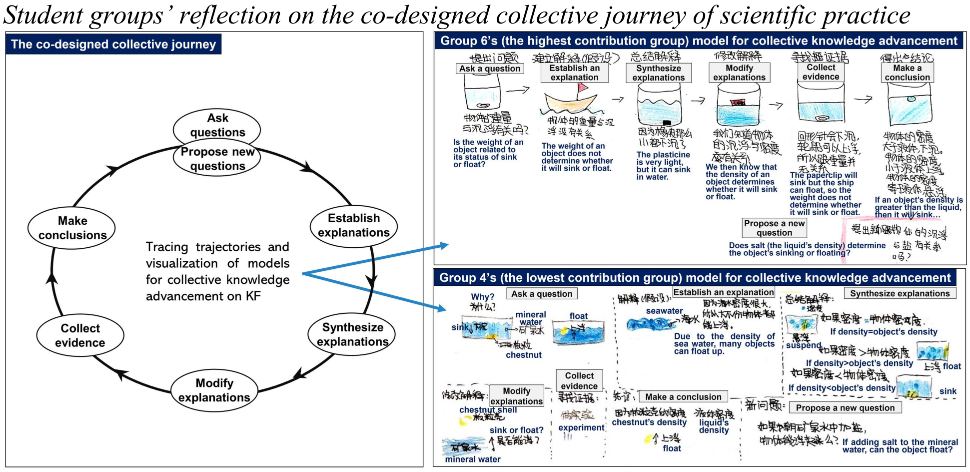
Students worked in collaborative groups based on their interests in the same research problems following the collective journey. For example, students s12, s13, s17, and s24 collaborated with each other in proposing a theory of the mechanism of Descartes diver. In addition to observing the phenomenon that "When there is more air in the Descartes diver, it will float; when there is more water, it will sink," they also identified such new problems as "How to make the floated plasticine sink into the water?" Thus, a new explanation was offered for the mechanism of sink or float, that is, "it depends on the average density rather than only the weight, the shape, or the density." Parallel with the journey of collective inquiry, students modified their initial explanations and went deeper into the collective inquiry. They modified explanations from the basis, conducted experiments, and generated new emergent questions. These different explanations and experiments were visualized on KF, which promoted students' contribution to collective knowledge advancement.

Theme 4. Reflecting on the designed collective journey and conceptualizing what collective knowledge advancement was promoted during scientific practices

Students not only engaged in the collective journey, but they also reflected on how their scientific practice process is aligned with the proposed collective journey model. Student groups discussed their understandings of how their inquiry into their selected problems on *Sink or Float* developed over time involving asking questions, proposing, synthesizing, and modifying explanations (theory), designing experiments and collecting evidence to test explanations, and emerging new questions. They traced back the trajectory and constructed models to frame the collective knowledge advancement promoted in this journey, as shown in Figure 3. The visualization of these different collective journeys as diverse models further supports collective knowledge advancement.

Figure 3

Student groups' reflection on the co-designed collective journey of scientific practice



Conclusion
This study contributes to the literature on knowledge building on how a designed collective learning journey of scientific practice supported young children to work as scientists as a community. Results support the positive roles of the designed environment in promoting students' contribution to collective knowledge advancement. Qualitative analyses suggest the trajectory of how students work with the problems for knowledge advancement. The study also illuminates the dynamics, processes, and trajectories of how young children can engage in the designed collective journey to deepen their inquiry and advance their collective knowledge. Future study is needed to examine the improvements of this designed collective journey and pedagogical designs and explore how progressive discourse was developed to advance scientific practices.

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