Using Social Media and Learning Analytics to Understand how Children Engage in Scientific Inquiry

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ABSTRACT
Children are increasingly using social media tools in their lives. In addition, there is great interest in understanding how to design and evaluate social technologies to aid in children's learning and development. We describe two research endeavors that begin to address these issues. First, we introduce SINQ, a social media application that encourages children to practice Scientific INQuiry skills through collaborative participation. Second, we conducted a case study of SINQ with six children, ages 8-11, and collected log data of their interactions in the app. We applied learning analytics on this log data using a visual analytic tool called LifeFlow. The event-sequence visualizations showed how children engaged with scientific inquiry within the SINQ app, and most importantly illuminated how inquiry is not a linear process with a defined start and end. The children in our study traversed the inquiry process via diverse pathways, all of which were supported by the SINQ app.

Categories and Subject Descriptors
H5.m [Information interfaces and Presentation (e.g., HCI)]: Miscellaneous.

General Terms
Design, Human Factors.

Keywords
Children, Social Media, Science Learning, Learning Analytics.

1. INTRODUCTION
Helping children learn and develop expertise in scientific inquiry practices is a difficult process and an enduring research area in education and the learning sciences. Scientific inquiry includes the ability to generate questions, construct explanations, assess sources of information, test hypotheses, and analyze data [10]. It also involves dispositions such as being curious about the world, using a process of inquiry to explore questions, and communicating one's ideas to a community of like-minded peers such as other scientists [7].

There is also a rising awareness that youths and children (12 and under) are increasingly engaging in diverse social media (SM) communities that include social network sites, social gaming, and project-sharing communities [2, 8]. However, few research studies have explored how to design social media for children and even fewer have focused on using data and analytics from social media to better understand children's learning processes [8]. In this study, we demonstrate how SM tools and learning analytics (LA) [3] of the data generated by such tools can aid in understanding children's scientific inquiry-based learning processes. This study is part of a larger design-based research project [6] in which we have undertaken an 18 month design process to develop an SM app for children's everyday science inquiry called Scientific INQuiry (SINQ) [1, 9].

In this paper, we first provide a short explanation of SM for learning and SINQ. We then describe a case study of SINQ with six children ages 8 to 11. We logged SINQ interaction data from February to May 2012, the bulk of which came from two sessions that took place on February and April. To help us make sense of this data, we used an interactive information visualization tool called LifeFlow [12]. LifeFlow enabled the discovery of patterns of interaction that enhanced our understanding of the ways children engaged with SINQ during the three-month period. We learned that the children in our case study did not always engage with scientific inquiry as a linear process that began with a question followed by hypotheses and investigations. Instead, children charted diverse pathways through the inquiry process.

This early work contributes to research on interaction design and children. We integrate several research streams in social media, children, and learning analytics [3, 8]. We highlight how LA can be used in conjunction with technology that is specifically designed for children, to shed light on important research questions for youth. Specifically, we show how visual analytics of data culled from our design project with children helped us learn more about how children go about scientific inquiry in settings outside of the formal classroom. We believe that these insights can be incorporated into future designs of SINQ and other social technologies for children. We followed two strands of inquiry for our study, asking:

1. What pathways do learners take as they use the SINQ platform for scientific inquiry? How do they enter into and navigate through the site, and what do these interactions say about their learning process?

2. How could data of users' interactions in SINQ inform the design of future learning technologies for children?

2. SOCIAL MEDIA AND LEARNING
We argue that popular social media tools offer native affordances to support socially constructed scientific inquiry practices, and that corresponding interaction design patterns can be derived from these features for designing more engaging scientific inquiry technologies. For example, SM platforms often **lower barriers to**

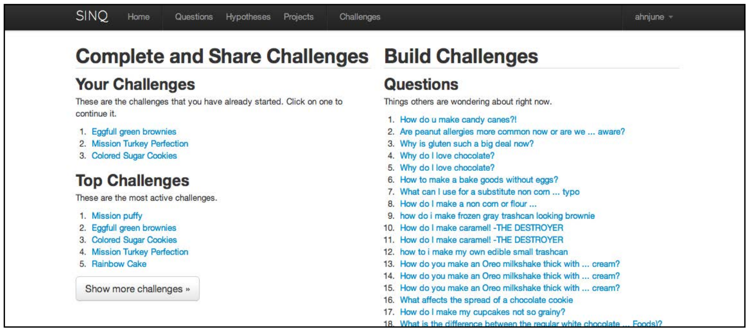

Figure 1. First prototype of SINQ. Members contribute elements of inquiry (e.g. questions, hypotheses, projects) to collaboratively create science projects (challenges) that they can implement.

participation by allowing individuals to make micro-contributions. Members tweet short, 140-character posts in Twitter™ or update Pinterest™ "pins" with graphical images that link to further information. The interaction design of these popular SM examples stand in stark contrast to how learning occurs in formal settings where students are asked to go through a complex learning process individually. Scientific inquiry is a substantial process, comprised of a series of cognitive tasks ranging from question formulation to information seeking, hypotheses generation, experimentation, data collection and analysis, and communication of findings. SM for inquiry learning could encourage children to split up those tasks and make smaller contributions that enhance their skills and encourage their participation.

Also, in social media platforms**, scaffolding is provided through collective feedback from one's networks**. For example, in Facebook™, individuals can "Like" posts to express social support of others. Simple features such as voting can act as strong, collective scaffolding mechanisms. Likewise, researchers have found that novice learners need explicit guidance (i.e., scaffolding) to perform tasks such as crafting an explanation of their scientific ideas, or organizing information resources to support their inquiry [11]. The SM mechanism of collective feedback could model the scaffolding process recommended by researchers in education and the learning sciences.

3. SINQ DESIGN

SINQ is a social media app designed for use within and across everyday, informal settings (e.g., at home, after school) [see 9]. SINQ could also be used in formal classroom settings, but has not yet been incorporated into formal contexts. The affordances of SM systems, coupled with our understanding of learners' scaffolding needs, motivated us to design the following features into an initial version of SINQ (Figure 1):

Allow Micro-Contributions and Lower the Cost of Participation: Learners can contribute small pieces of an inquiry process, reducing the complexity and cognitive load required of each learner. Members of SINQ can contribute stand-alone elements (e.g., a question, hypothesis, or project), or add new elements to others' contributions (e.g. add a hypothesis to someone else's question).

Design the Platform to Aggregate Micro-Contributions into Coherent Wholes: Individual learners can observe how their small contributions combine to create larger inquiry projects. Through this process, learners can contribute in ways they are capable of, but gradually learn about other pieces of the scientific inquiry process.

Leverage Social Vetting to Provide Collective Feedback: Members of SINQ can give feedback on (e.g., vote) their peers' contributions. SINQ displays this collective data to learners to help them improve their contributions and skills.

4. METHODS

Since it was still an open question of how (and whether) learners would take advantage of SINQ's affordances, we conducted an exploratory study to examine how learners used SINQ, what learning pathways they took in the platform, and how these user experiences could inform both our understanding of collective learning and future design iterations.

4.1 Learning Context

We deployed SINQ in an afterschool program called Kitchen Chemistry (KC), that engaged elementary school children in scientific inquiry projects through cooking [4]. A total of six children, between the ages of 8 and 11, participated in KC. They used SINQ to create potential cooking projects. For example, we observed learners adding questions such as "how do I make green brownies or greenies?" Other children then added hypotheses (e.g. add green food coloring) and investigation ideas (e.g., make different brownie recipes) in ways that enhanced the children's inquiry process [5]. These examples illuminate how everyday activities like cooking can turn into opportunities for children to practice scientific inquiry skills such as questioning, hypothesizing, and experimenting. The participants were free to interact with SINQ in any way they felt comfortable, and the platform was designed to log detailed data points of their actions. SINQ's logging features enabled us to apply learning analytics techniques to examine the ways in which learners were participating in the scientific inquiry process.

4.2 Learning Analytics: Log Data and Information Visualization

As noted above, SINQ collects detailed log data of user actions. We coded contributions of a question, hypothesis, project, or result as **Primary actions**. **Secondary actions** were contributions of topics, resources, and voting attached to primary actions. Entries in the log data detail an action type, the user that carried out the action, the time stamp at which the action occurred, and a list of properties of the action.

This longitudinal interaction data were inputted into the LifeFlow information visualization tool [12]. LifeFlow generates information visualizations from longitudinal log data that allow analysts to understand how sequences of actions take place in large datasets. Figure 2 shows a visualization of color-coded action sequences constructed from KC interaction log data. Each

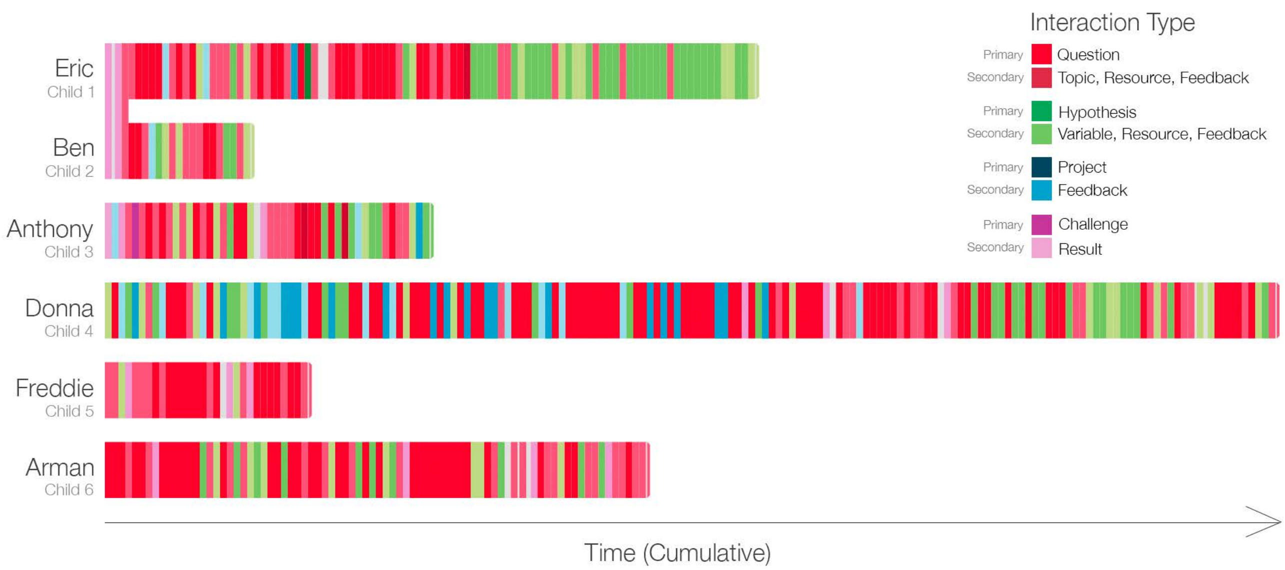

Figure 2: Longitudinal Information Visualizations of Learner Activities in SINQ. Each line represents a child's sequence of interactions. Colored blocks correspond to primary and secondary contributions to SINQ that match aspects of inquiry. Actions are ordered in sequence and are left justified (e.g. the children did not all begin their sequences at the same time, but the visualization displays all sequences beginning with the first action in the left-most block.

child in the KC program is represented with a pseudonym and a single line of their sequence of actions in SINQ. Each color-coded rectangle in this visualization represents exactly one action taken by a user. Repeated events (e.g. sequential events of the same type, next to each other) appear as larger blocks. Relatively thin rectangles depict actions followed shortly by another action. Each horizontal sequence of rectangles represents a timeline of actions for a single child, ordered from left to right from least to most recent.

5. FINDINGS

The information visualization (Figure 2) illuminated various aspects of learner experiences in SINQ. Here, we detail how the visual analytics enhanced our ability to observe the diverse pathways that children took through the inquiry process.

Entry Points to Inquiry. Some KC learners began their SINQ interactions by exploring and asking questions (sequences beginning with red blocks, such as Arman). This finding supports the traditional belief that learners begin an inquiry process with an exploratory question. Other children began by adding results to existing challenges, which are fully developed projects on SINQ (pink blocks, see Eric & Ben), or voting on hypotheses (green blocks, see Donna) before moving on in their inquiry process. For example, Donna begins by voting on a hypothesis (green block) before entering a question (red block) and then exploring projects (blue block) and other hypotheses (green block). It appears that Donna began her inquiry process by examining ideas of cause and effect, and orienting herself to her peers' thought processes, before contributing her own question. Such a result illuminates how different learners will gravitate towards diverse elements of a scientific inquiry process when they first enter SINQ. We posit that with a larger sample of SINQ users, and varying learning contexts, one would observe even more diverse entry points to inquiry.

Diverse Pathways through Inquiry. The most striking finding from the event-sequence visualizations was the quite diverse ways in which the children experienced scientific inquiry. The children's' pathways through scientific inquiry in SINQ were varied and unique. In particular, we honed in on contributors of primary actions. For example, what led different learners to contribute an actual piece of the inquiry process to SINQ (a question, hypothesis, or project)? The log data visualizations reveal that children exhibited differing activity levels related to component tasks within the inquiry process.

Some children contributed many questions, or secondary actions related to questions, in their interaction sequences. For example, Freddie and Arman show many red and light red rectangles, which signify that they spent considerable time engaging with others' questions (e.g. voting on them) and writing their own questions. Eric showed a variety of interactions towards the end of his inquiry process that suggested a developing focus on hypotheses (green blocks). He explored questions and projects first, which led him to begin to engage more deeply with causes and effects. Anthony and Donna show very diverse engagement, jumping freely between questions, hypotheses, and projects.

The sequence visualizations can also shed light on how deeply children engaged with inquiry in SINQ. Some sequences are longer (e.g. Donna) and others short (e.g. Ben), and illuminate how different children contributed to the SINQ platform over time. Overall, these diverse interaction sequences confirmed for us that a social media tool like SINQ affords children opportunities to immediately participate in an inquiry process through areas that they most feel inclined. The information visualizations also clearly highlight how learners take different paths that lead up to their being able to contribute a piece to the scientific inquiry process in SINQ. Some children dove right in and directly contributed a question (e.g. Arman). Some children "hung out" and completed secondary actions like voting on their peers' contributions, before they directly added their own (e.g. Donna). It appears that SINQ afforded learners the opportunity to observe others' contributions, and actively participate in other ways by voting or adding additional information, before they felt comfortable contributing their own questions, hypotheses, and projects. These findings reiterate how the process of inquiry for different learners progressed via diverse pathways. These patterns of learner interactions, culled from SINQ log data, provide an initial validation that our purposeful design choices in SINQ allow learners to enter into and contribute to an inquiry process via segments they feel most comfortable. In addition, once a learner enters the SINQ platform, they are eased into other parts of the inquiry process.

6. CONCLUSIONS

Our initial explorations into log data and visual learning analytics were intended to help answer the question, *how could data of children's interactions in SINQ inform future educational interventions and design changes in the SINQ platform?*

Although the exploratory study was limited to a sample of six children in one learning context, the sequential visualizations helped us observe the diverse trajectories learners could have when using SINQ. Our findings suggest several guidelines for designing SM and LA to support scientific inquiry. One clear design opportunity is to collect deeper data on each individual learner in SINQ to create profiles of their inquiry skills. A SINQ user that often engages with creating projects may in fact be signifying a particular learning preference or area of expertise. That learner may prefer more active elements (such as completing projects others have created) or show particular expertise in crafting well-conceived projects that build from others' questions and hypotheses. Similarly, a learner who often engages with questions in the SINQ platform may be signifying a deeper curiosity about the world. In SINQ, diverse learners are able to engage with the aspects of scientific inquiry that most resonate with them. In addition, the platform can collect interaction data. With the help of various analytics strategies, one could begin to identify and show learners areas in which they might increase their scientific activity and skills.

Our analytics also highlight design opportunities for scaffolding learner transitions between activities within the scientific inquiry process. For example, the use of visual analytics in this study showed how children transitioned between different parts of the inquiry process. Anthony begins by examining projects and challenges, before devising a question of his own. Arman enters a question right away, before exploring other existing challenges, then writing another question. Donna votes on a hypothesis, enters her own question, votes on a project, and then enters her own hypothesis. These insights suggest opportunities to design optimal transition points for learners. What is a child's thought process when they follow Arman's or Donna's sequence of activity? Further qualitative research in conjunction with the type of learning analytics in this study, could shed light on such learning processes.

The sequential pathways that learners take in SINQ suggest diverse thought processes. The child who contributed a question, hypothesis, and project, may well have a different thought process than the child who spent considerable time voting on others' contributions, then jumped between challenges and questions. By utilizing log data of learner interactions, we have begun to better understand what these transitions and pathways might look like, and how to design better supports for children as they engage with inquiry in science.

Our exploratory work makes several contributions to the understanding of social media design that support children's learning processes. We show how designers can operationalize tasks and subtasks in a technology that can signify children's engagement with learning. In SINQ, we operationalized tasks in the scientific inquiry process (e.g., posing questions, evaluating others' hypotheses through "voting", devising experiments by articulating projects to test hypotheses, etc.), which allowed us to apply learning analytics techniques to the log data. Through this process of combining design, children, and learning analytics, researchers can glean deeper insight into how children use a tool and its reflection on their learning process.

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