Constructing Scientific Arguments with User Collected Data in Nomadic Inquiry

Abstract
Mobile devices now enable students to engage in nomadic inquiry as they collect large amounts of data from the environment to answer scientific questions. To support them with constructing scientific arguments, we created CogniBits: a system designed for tablet devices that scaffolds students through creating scientific arguments with user-collected data. The system was iteratively designed with two students and seeks to address the additional challenges these opportunities bring to science inquiry.

Keywords
Nomadic inquiry, argument creation, tagging, scaffolding, learner-centered design

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces - User-centered design
K.3.1 [Computers and Education]: Computer Uses in Education – Computer-assisted instruction

General Terms
Design

Introduction
Science inquiry, the process of posing questions and gathering and evaluating empirical evidence to develop...
scientific arguments, is a central tenet of national reform efforts, and a key component of science education [1]. With the emergence of low-cost but feature-rich mobile devices, it is possible to support inquiry on-the-go, or “nomadic inquiry”, in a variety of settings [4, 5]. These devices can enable and assist students as they collect, organize, and annotate multimedia data from informal learning environments such as museums and parks.

The motivation for our research is to create and explore the idea of a modern scientist’s notebook to seamlessly support students with nomadic inquiry across formal and informal contexts. Nomadic inquiry makes a new variety of activities possible; students can investigate open-ended driving questions and collect and annotate large amounts of rich, multimedia data from the environment [4]. These opportunities create new challenges for students, as their investigations can have multiple potential correct answers and use a student defined data set, containing both appropriate and potentially inappropriate data [3].

To explore supportive tools for nomadic inquiry we began the Zydeco project, which includes web and mobile tools to enable students to set up science investigations, plus collect and annotate data [4]. As part of the Zydeco project we are now exploring a new component, CogniBits, on tablet devices to help students develop scientific explanations. Science investigation culminates with argument synthesis, where students peruse the evidence they collected, make and revise claims to answer the driving question, and backup these claims with evidence and their associated reasoning [7]. In order to examine the data collected to construct the argument, it would be advantageous to have a larger display, such as a tablet. We developed CogniBits, an argument synthesis system designed for large touch tablets (i.e. the Apple iPad) in order to determine how to scaffold students (aged 11-14) performing nomadic inquiry to synthesize their multimedia data to create a scientific argument. While we intend to combine the data collection and annotating process on the iPad, we are utilizing the Zydeco application for the initial exploratory studies.

Prior Work
There have been a variety of previous systems developed to help students develop arguments. For example, Belvedere helped students to create inquiry diagrams to construct their argument, enabling them to link together multiple causal ideas and pieces of evidence [10]. ExplanationConstructor supported students as they put together an explanation for specific scientific questions, following tailored explanation guides where students worked through each step to answer proposed questions [9]. WISE allowed students to collect data from the web and put together claims, evidence, and their explanations to explore open-ended driving questions [6].

This previous research has used a variety of methods to support argument construction: utilizing prompts and supports throughout the process, enabling students to give peer feedback at a midway point to encourage reflection, and providing concrete methods for structuring their argument. While we are building on many of the concepts of these previous tools, none of these systems support argument synthesis for students utilizing large amounts of multimedia data collected from the environment and shared with their class.
System Overview
CogniBits uses a learner-centered design process to address two goals: (1) helping students explore and interpret their class's multimedia data, and (2) supporting students in using this data to put together a scientific argument [8]. This is done primarily through:

- Using tags to annotate, organize, describe, and facilitate the search of multimedia collected data
- Creating the explanation with the Claim, Evidence, and Reasoning framework [7]
- Dynamic prompts and feedback

These supports were influenced from research identifying the motivations behind applying tags to photos, which were found to be a combination of social/personal and communicative/organizational [2]. During the inquiry process, tags used to annotate data serve both a socially and personally communicative purpose that we utilize as part of the educational activity, in conjunction with using the tags for personal organization to support searching and usage of data.

In the following scenario we illustrate how a student uses CogniBits to support argument construction. We are highlighting the supports we used to tackle the new challenges that occur with argument synthesis in our nomadic inquiry collection context. In order to provide perspective for this, we will briefly summarize the nomadic inquiry leading up to argument synthesis, for which we are utilizing the Zydeco system [4].

Classroom Preparation and Nomadic Inquiry
Mrs. Hammond, a 7th grade teacher, explains to her class that they will be visiting the history museum as part of an exploration into how different characteristics might influence an organism’s survival. The driving question she gives students is: “Create a new animal that could survive near Michigan during the Cretaceous Period”. The class brainstorms sub-questions they should collect data under, such as defensive and eating traits, and develops a list of characteristics about the animals and plants that they could use to tag any observations or information they find in the museum.

Using Zydeco, Alice collects 12 pieces of multimedia data. Her first was a photo of a Tyrannosaur, which is collected under the category “Other animals in the habitat” and titled “T-Rex Skull.” She tagged this photo with “eats large animals”, “eats medium animals,” and “eats small animals.” She also records a voice note to describe something interesting she discovered, namely its long heavy tail balances its skull.

Argument Synthesis
After reviewing her data with the class to help understand her findings, Alice initiates the CogniBits program; a single claim canvas is brought up (Figure 1). The driving question, always visible at the top of the screen, is addressed by making a series of claims that are each backed by multiple evidences and supported by reasoning. Alice knows that the Tyrannosaurus will try to eat all the other animals and decides to start with a claim about how her animal defends itself against an attack, writing, “Heavy armor helps my animal defend itself in the Cretaceous Period.”

The main screen is focused on displaying the current claim the student is working on, and has three primary buttons for input, each titled according to which part of the claim, evidence, reasoning framework they assist.
with. Alice taps on the evidence tab, which brings up a view showing all the evidence the class collected (Figure 2). Since her claim used the word “armor” in it, the system automatically brings up all the results tagged “armor” as it parsed her claim and applied any search terms that matched words in it. She decides she wants to also search for data related to being strong, and taps the “strong” tag in the sidebar to add it to her search. In the system, we describe a tag as a “label” to make it easier for students to understand.

After scanning through the thumbnails of data, Alice finds a photo she is interested in learning more about. She pinches the photo to zoom in, enlarging it to fill the screen and providing detailed information (Figure 3). Each data point was annotated with a category (which was a sub-question the data was collected under) and the tags that were applied to the data to describe its characteristics and/or function.

Alice reads through the tags, determines that she does not want to use this evidence, and begins swiping through additional data and iterating her search results. An Ankylosaurus fits her need, so she taps the “Use” button. She is then asked to select which tag(s) best describe the reason she wants to use this data as evidence, prompting her to reflect again on why she wants to use this data. Alice taps the “armor” tag, which then attaches the data to her claim.

Now Alice needs to provide reasoning for her claim and evidence so she taps on the reasoning tab. Since she is working on her first explanation with the system, it provides possible reasoning templates. If she chooses an inappropriate reasoning template, the system scaffolds her through the process of determining appropriate reasoning via a series of prompts. However, she decides to enter her own reasoning. After Alice enters in her reasoning she reviews the finished claim (Figure 4).

Looking at her claim, Alice decides she wants to add a second piece of evidence for additional support and returns to the evidence page, this time touching and holding on the photo of the Ankylosaurus to have the system find similar pieces of information. The Ankylosaurus data had three associated tags which are now applied as search terms and the most pertinent results are returned first. She selects and uses another piece of data and includes this into her reasoning.
Alice continues this process and ends up with three supported claims as to how and why her animal will survive. After the entire class is finished, the teacher calls on Alice to present her argument. She hits the “Present” button and holds up her device, displaying the full screen presentation of her claims that the system automatically compiles. Alice is able to describe to the class the animal she designed and why it will survive, one claim at a time, utilizing her selected data and playing back any audio or video she desires.

Iterative Design Process
CogniBits was iteratively designed with two children (aged 13-14) over five, two-hour sessions. At the initial design session, the children were given background knowledge about the framework and what sort of data we would be using, and we sketched out and discussed a variety of different design ideas. Each session yielded new ideas and perspectives. There was a two-week gap between each session where the ideas from the previous session were implemented and kids could use the working prototype and offer additional suggestions and design ideas.

While this largely influenced many small details of the design, there were several notable suggestions and observations from the sessions:

- Exploring the evidence and seeing what tags were applied was the students’ favorite part of the activity.
- They both appreciated the ability to quickly find similar data using the touch and hold gesture.
- They experimented with different gestures to clear the tags they were using to search, such as a five-finger press and a three-finger swipe, but were happiest with a single swipe to the left or right to trigger the action.

Contributions and Next Steps
CogniBits is a work-in-progress system being developed to support the argument synthesis portion of nomadic inquiry on a large mobile touch device (i.e. the iPad). The software was designed to handle open-ended questions where students collect large amounts of tagged multimedia data and then explore their class’s data and synthesize an argument.

This research is helping us see how to support students as they explore, organize, and synthesize large collections of multimedia data, with the specific intent
of using this data to construct arguments. We focused on utilizing tagging as a means of integrating the entire nomadic inquiry activity and using tags as communicative, educational, and organizational supports. While tags have been utilized for these general purposes in other applications, they are showing promise in supporting learners in this context. What we learn could assist other designers seeking to support annotation and later exploration and usage of digital objects for educational purposes.

We are expanding our pilot testing of CogniBits to include small groups of 3-4 students over several months to further iterate the design, and will then be testing the system with a full classroom of students (aged 11-14) in April to see how they utilize the system and learn more about what scaffolds the students need as they construct arguments.

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**Citations**


