ZOOWISE: WEB-BASED DESIGN FOR LEARNING *IN* AND *ABOUT* SCIENCE

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ABSTRACT
Grounded in contemporary perspectives on learning science as inquiry and built upon empirical research evidence pointing to the significant role of technology tools in supporting this kind of learning, we present a framework that informed the design of a web-based science inquiry task on endangered animals called ZooWISE. The overarching principle guiding our framework is learning science as inquiry with an emphasis on model-based reasoning. ZooWise integrates both content and process learning and addresses cognitive, epistemological and social goals of science. The framework has implications about the design of web-based learning environments aiming at enhancing science learning as inquiry, learning about the nature of science and developing an understanding of the work of scientists.

KEYWORDS
Web-based, science, learning, evidence, explanations

INTRODUCTION

Contemporary reform documents emphasize the engagement of students into scientific practices that support learning science as inquiry (NRC, 1996, 2000). This kind of learning, as the literature illustrates, can be supported with the use of technology tools in science teaching and learning. In fact, growing evidence from a number of studies provides support to the argument that technology tools have the potential to engage students in scientific inquiry (e.g., Linn, 1991; Pea, 1993; Songer, 1993). Taken together these two perspectives on learning science provide a powerful approach to supporting science learning. Such an approach to supporting science learning is at the heart of the account of the framework that informed the design of a web-based science inquiry task within the context of endangered animals and which is described in this paper. The aim of this web-based science inquiry task is to scaffold science learning through inquiry and address cognitive, social and epistemological domains of science.

The content focus of this web-based inquiry science task, called ZooWise, is on endangered animals and builds upon the work done by the World Conservation Union (IUCN) for evaluating the degree of extinction threat of a species. This inquiry-based task is geared towards children of the age of 11-13 years old and invites them to work in small groups with the aim of constructing evidence-based claims about whether a species meets the extinction criteria risk and should be placed on the Red List of threatened animals. There are seven categories of threat in the IUCN Red List system: *Extinct*, *Extinct in the Wild*, *Critically Endangered*, *Endangered*, *Vulnerable*, *Lower Risk* and *Data Deficient*. The criteria that are used to evaluate the degree of threat are the following: a) Population Reduction; b) Restricted area of population; c) Population size; d) Mature population of less than 50; and e) Quantitative analysis of the probability of extinction. ZooWise presents these criteria through a number of activities and then invites students to make use of those along with examining data to make decisions about the degree of extinction threat of five different animals. The task as described in the introduction of ZooWise is as follows:

> In this scientific inquiry, you and your classmates will be given an animal to study. Your job is to decide whether that animal should be place on a list of animals threatened with extinction, called Red List. In order to do so, you will engage in conducting investigations through which you will examine five criteria that scientists employ to make similar decisions. Maria, a young scientist who was born in South Africa and now works at the London zoo doing research on animal extinction will be your guide through this process of decision making. Your final product will be a PowerPoint presentation that states your claim: 'Do Red List' or 'Don't Red List'. Your presentation must refer to relevant scientific evidence that supports your claim. Based on the quality of your report, you and your classmates may be invited to participate to a 'Red List Conference' sponsored by the Zoological Society of London held at the London zoo.

In the first set of activities, students are presented with pictures of some animals that are threatened with extinction in different parts of the world and are asked to report whether and what they know about each of those animals. Some examples of these animals are: Woody Spider, Monkey, Black Faced Lion, Sumatran Tiger, Red Panda, Sloth Bear, Pygmy Hippopotamus, Lemur and others. The purpose of this activity is to introduce students to the task and also for the teacher to get an understanding of the students' existing knowledge (see Figure 1).

Figure 1. Introduction to the work of World Wildlife Fund

The next set of activities deals with five animals that are used as exemplary cases of illustrating each of the five criteria of extinction, even though, they do not clearly match each of those, as data are missing, are anomalous or conflicting. The animals are: the *Ethiopian Wolf*, the *Arabian Oryx*, the *Black Rhino*, the *Golden Lion Tamarin* and the *Partula Snail*. In these activities students are engaged in a process of collecting data through available resources and suggested web-sites, evaluating that data and making decisions about which of that data could be used in the construction of scientific claims. The goal is to engage students in a process of constructing evidence-based claims about whether an animal is threatened with extinction or not communicate that claim to a public forum and engage in conversations with other groups who have worked with other animal cases.

DESIGN FRAMEWORK

Design Strategies:

ZooWise is built within the Web-Based Inquiry Science Environment (WISE) designed by researchers at the University of California, Berkeley. As Linn, Clark and Slotta (2003) described, WISE research is driven by a knowledge integration perspective. According to Linn (2000), knowledge integration is "the dynamic process of linking, connecting, distinguishing, organizing and, structuring 'models' of scientific phenomena" (p. 783). In this case, the word model is used to refer to patterns, templates, views, ideas, theories, and, visualizations. Linn, Clark and Slotta (2003) described the main features of WISE environment: "WISE incorporates an inquiry map to communicate the patterns that students follow to investigate a topic…it incorporates prompts to help students reflect as well as monitor their progress…it includes hints and evidence pages designed to add ideas about the topic the student is researching" (p. 522).

The design framework of WISE environment is organized around four design strategies: make science accessible, make thinking visible, help students learn from one another and foster lifelong learning (Linn & Slotta, 2000). In addition to these design strategies, the design framework that characterizes ZooWise focuses on the processes of scientific inquiry and particularly reasoning about data. More specifically, the design framework that characterizes ZooWise is that of scientific inquiry (NRC, 1996) with an emphasis on model-based reasoning and one that models, in some sense, the work of scientists (Chinn & Malhotra, 2002).

The design of this web-based inquiry task builds upon perspectives on learning science as inquiry and emphasizes on the epistemological conversations surrounding the acquisition of data and the subsequent transformations of data to evidence, evidence to models and models to explanations (Avraamidou & Duschl, 2004). ZooWise integrates both content and process learning and addresses cognitive, epistemological and social aspects and contexts of science. Within these contexts the focus is on scaffolding students' reasoning about data within the context of endangered animals and developing contemporary understandings about the nature of science and the work of scientists through processes of data evaluation and construction and communication of evidence-based claims.

Science as a social process of knowledge construction:

The design of ZooWise draws upon the ideas of Joseph Schwab (1962) who argued about a presentation of science as a product of *fluid enquiry*, defined as, 'a mode of investigation which rests on conceptual innovation, proceeds through uncertainty and failure, and eventuates in knowledge which is contingent, dubitable, and hard to come by' (p. 5). Schwab's definition not only suggests the view of science as an investigation instead of a product, but it also points to the notion that science is not viewed as a static set of facts that represent a spectrum of absolute truths. Based on these ideas, ZooWise invites students to work in groups with the aim of conducting authentic investigations and constructing evidence-based claims within the context of animal conservation. Thus, the task provides students with the responsibility of constructing their own understandings and it scaffolds this process through a variety of tools and activities.

Contemporary trends in learning theory portray new perspectives on how people learn and particularly how students learn and how teachers can support their learning. These perspectives refer to what people should learn and what their roles are in the process of learning. As Brown (1994) stated, "learners came to be viewed as active constructors, rather than passive recipients of knowledge…learners were imbued with powers of introspections, one verboten" (p. 6). These new perspectives about how people learn and the design of learning environments have inevitably influenced ways of thinking about teaching and learning as well. More specifically, current perspectives of learning and instruction are focused on learning environments that are designed to encourage students to integrate information instead of merely being provided with it by the teacher (Linn, 1996). According to this view, meaningful learning occurs when learners actively construct their own learning outcomes (Bruner, 1961; Mayer, 1992; Wittrock, 1990). We agree with the view that the learning of individuals is a constructive and iterative process in which the person interprets events on the basis of existing knowledge, beliefs and dispositions (Borko & Putnam, 1996) and we take on Shuell's (1996) description about how individuals construct their own knowledge:

> The learner does not merely record or remember the material to be learned. Rather, he or she constructs a unique mental representation of the material to be learners and the task to be performed, selects information perceived to be relevant, and interprets that information on the basis of his or her existing knowledge and current needs (p. 743).

The design of ZooWise takes into consideration this view and provides with the use of specific scaffolds, opportunities for users to report their existing knowledge throughout the main activities. An example of such a process is an activity that uses *Wise Note*, and invites students to work in pairs and report what they think it was the problem for Partula snail, before they look into the data provided to them.

Another central feature of the design of ZooWise is that it invites students to work in groups to conduct their investigations and construct evidence-based claims and then communicate those claims to their peers within a public forum. This design strategy is influenced by sociocultural perspectives on learning and particularly Vygotsky's theories arguing about the inherently social nature of learning. Moreover, this design strategy drawn, in part, upon views suggesting that cognitive apprenticeship is central in the social activity within which learning occurs (Collins, Brown & Newman, 1989). According to Derry and Lesgold (1996), cognitive apprenticeship denotes the sharing of problem-solving experiences between novices and mentors who work together and negotiate their understandings through dialogue which publicly exposes knowledge and thinking processes involved in their joint problem solving. In the case of ZooWise, 'mentoring' is provided through the scaffolds, the teacher and the students who work within groups towards achieving shared goals through joint problem solving activities.

Model-based science:

Our attempt to develop a theoretical framework for the design of ZooWise in order to enhance students' understandings of the nature of scientific knowledge is grounded on Giere's (1988) view of models as representation of the world and theories as families of models. This model-based view of science has the advantage, according to Giere, of allowing one to talk about models 'fitting' the world than of the truth of statements. This global perspective of scientific processes has the advantage over rival instrumental-based and justification-based philosophies of science in that it can embrace, where the others cannot, the inherent variation and complexity of the natural world and cognitive processes that seek to make sense of that world. According to Giere (1986), these cognitive resources and interests, combined with various judgmental strategies, provide the *mechanisms* – the analogs of genetic mechanisms in organic evolution – which drive the evolution of scientific fields. And this evolution takes place in an 'environment' of cultural and material resources required to support modern, high technology research…cognitive models represent some of the *mechanisms* by which various interests influence the evolutional development of scientific fields. The remaining enterprise is to work out the details of this process. (Giere, 1986, p. 324). The recent attention in educational research to understanding the design of learning environments (Bransford, Brown & Cocking, 2000) that support the development of cognitive resources, interests, judgemental strategies and mechanisms for the purpose of developing, in this case, learners' scientific understanding, is on our view, an enterprise quite similar to that proposed by Giere. So, too, is the need to pay attention to the details of the processes of the construction of scientific knowledge – details, which, we argue are best practices through reasoning about data.

Reasoning about data:

ZooWise places an emphasis on the role of data in science and processes such as reasoning about data to construct explanations. In the case of Partula snail, for example, information is provided, which could be used as evidence to support a claim about the degree of extinction threat of Partula. After an introduction to the story of Partula through a narrative, the students are provided with data presented in means of graphs, tables with population numbers and web sites. They are then asked to review these data and evaluate them in order to construct an evidence-based claim about whether Partula snail should be placed on the Red List or not (see Figure 2).

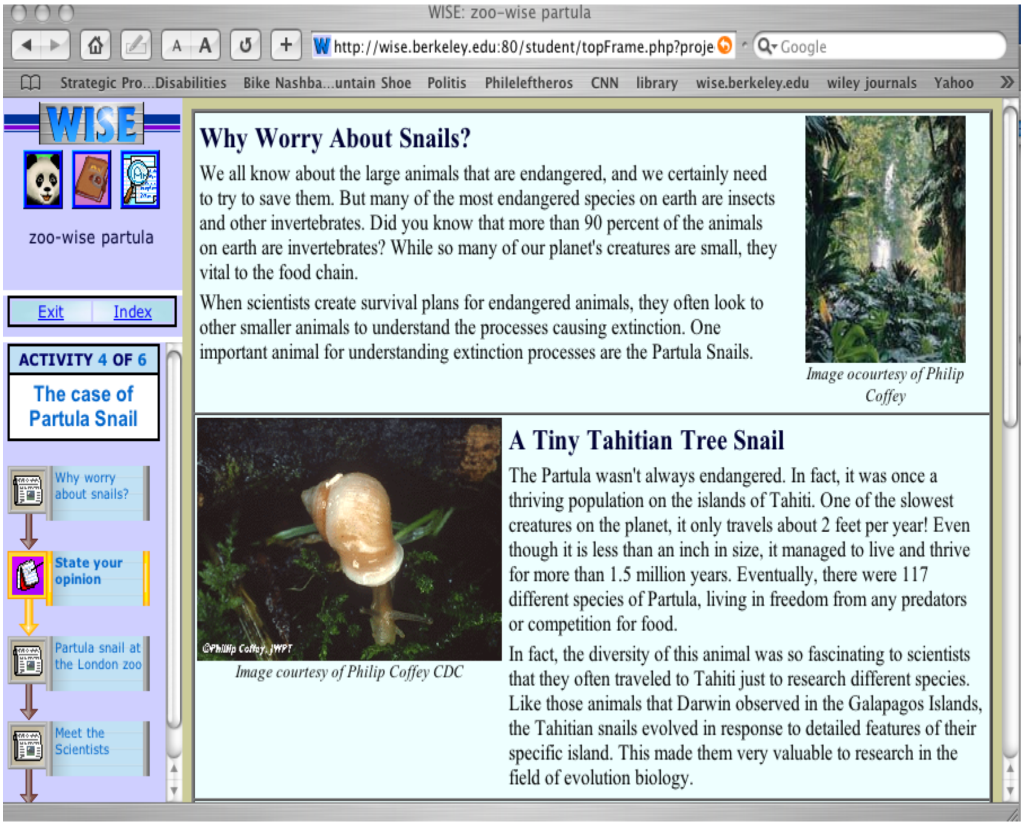

Figure 2. The story of Partula snail.

We argue that it is important to emphasize the process and procedures of data transformation in the process of constructing and communicating explanations: the *evidence-explanation* continuum (Avraamidou & Duschl, 2004). Our intent is to suggest the linkage between data and explanations is evidence, which results in an account of the processes of data transformations and uses. What makes the Evidence-Explanation approach different from the traditional approaches to science education is the emphasis on the *epistemological conversations* that, we maintain, lead to the construction of scientific knowledge. Central to these conversations is the act of justification. Justification processes are connected to the question: how and why certain evidence supports an explanation or why an explanation is more appropriate than others.

The critical transformations or judgements in the evidence-explanation continuum include: a) Selecting data to become evidence; b) Using evidence patterns of evidence and models; and c) Employing the models and patterns to propose explanations. Another important judgement is, of course, deciding about the selection of data itself. These decisions and judgements are critical entities, we argue, for explicitly teaching students about the nature of science (Duschl, 2000). How raw data are selected and analyzed to be evidence, how evidence is selected and analyzed to generate scientific explanations are important 'transitional' steps in doing science. Each transition involves data texts and making judgements about 'what counts'. ZooWise invites students to engage in similar practices through a process of constructing evidence-based claims and communicating those in a public forum.

Argumentation:

Throughout the activities of ZooWise, students engage in processes of constructing and communicating evidence-based arguments. More specifically, the goal of the second activity, which invites students to think about and evaluate data on the two imaginary animals, is for students to construct a claim about which one of the two animals is better able to take care of itself and use evidence to support that. Likewise, in the activities regarding the five different animal cases, students are asked to construct an evidence-based argument about whether that animal meets the criteria for extinction and should be placed on the Red List of threatened animals (see Figure 3).

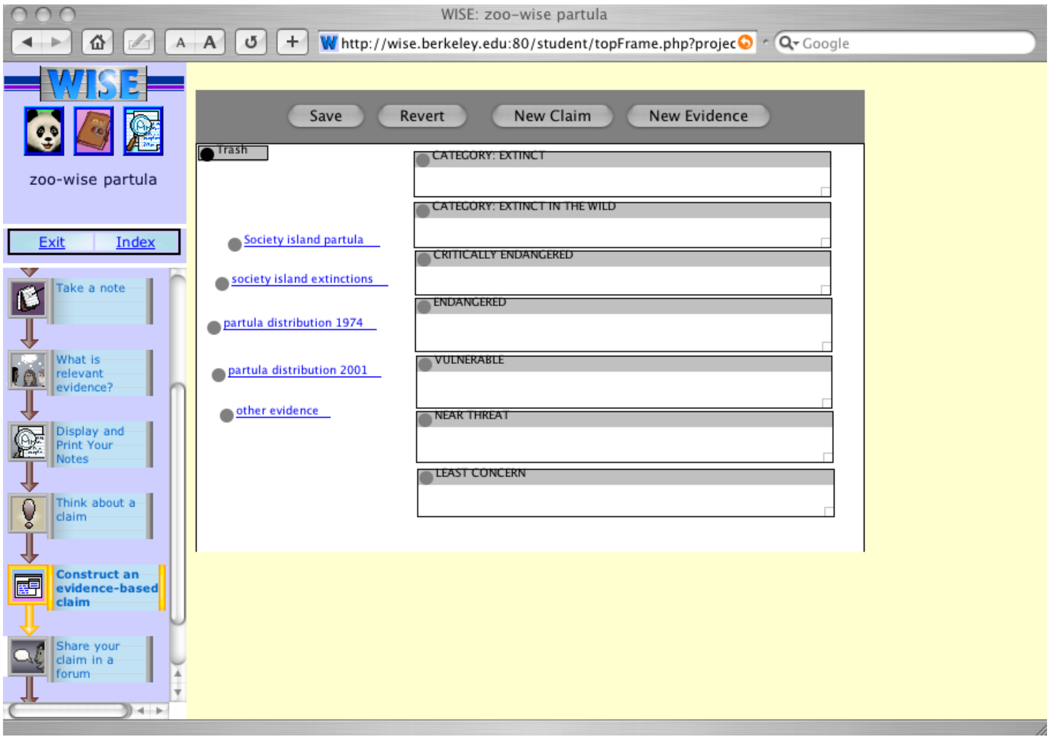

Figure 3. Evidence-Based Claim

In the last set of activities students are asked to communicate their claims to their peers in a discussion board and engage in asynchronous conversations about their arguments. The design principle upon which these activities were built on is based on the well-grounded assumption that the ability to develop arguments is central to developing understandings of the world and sharing these understandings with others. Engaging in the construction of scientific arguments as a way of learning science has been emphasized by a number of researchers (e.g., Driver, Newton, & Osborne, 2000; Kuhn, 1993).

Nature of science and the work of scientists:

We argue that ZooWise has the potential to enhance students' understandings of the nature of science, and more specifically the nature of scientific knowledge and how that is constructed. First, this task is structured in the form of scientific inquiry, which models in some sense the work of scientists, as it engages students in investigations with authentic data. Second, it portrays a realistic picture of science where in some instances data are anomalous, missing, conflicting, unclear and problematic. It does so by providing authentic data on the five animal cases that are fuzzy, messy and in some cases, anomalous, thus they do not lead to clear-cut judgments about the risk status of each of the animals. Third, it provides authentic narratives by zoologists who do field studies on the animals that are presented in the task. In the case of Partula Snail, for example, a link to the web site of the London Zoological society which describes the work being done by zoologists in London aiming at conserving Partula (see Figure 4). These types of connections of the task with related real-world research practices, we argue, have the potential to support learners' understandings of the nature of science.

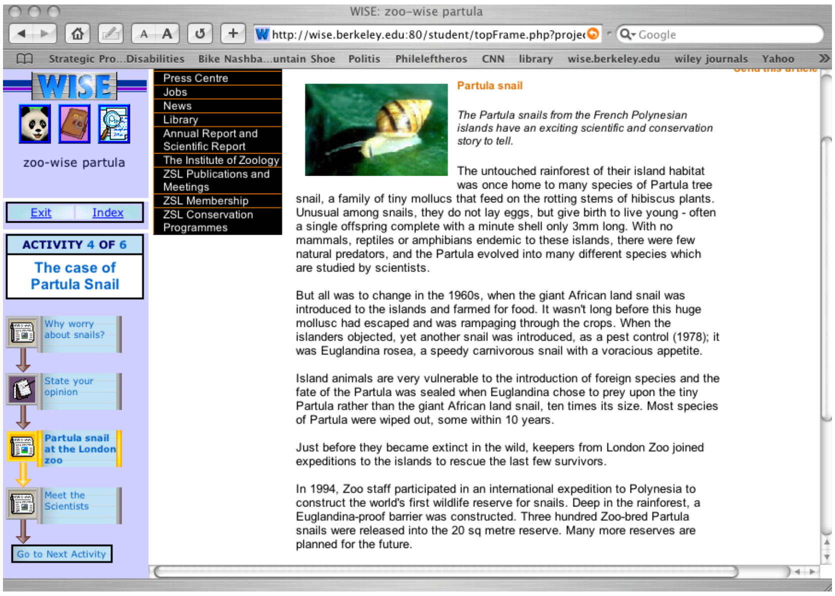

Figure 4. Partula snail at the London zoo

CONCLUDING THOUGHTS

In this paper we attempted to make the case for the design of a web-based science inquiry task in support of learning science as inquiry with an emphasis on model-based reasoning and developing contemporary understandings about the nature of science and the work of scientists. We built our case on Giere's (1988) views about model-based science and drew upon theoretical perspectives on learning science as inquiry and scaffolding this kind of learning with the use of technology tools and specific tasks. We presented a theoretical framework upon which the design of ZooWise was based and we discussed how specific activities have the potential to support science learning.

Through these activities, an emphasis is placed on reasoning about data within the spectrum of the evidence-explanation continuum. An important conceptualization of the evidence-explanation continuum is that it refers to both the *content* of explanations and the *process* of explanation construction. The content of explanations refers to the nature of explanations, their validity and the nature of the grounds that support them. The process of explanation construction refers to the interactive and dialectic process of reasoning about data and constructing and communicating privately held evidence-based explanations to a public domain. Through this process and within such dialectical contexts where negotiation of reasons and understandings takes place, we argue, a change in scientific understandings occurs. Such a change, we maintain, considers not only cognitive, but also epistemological and social aspects of learning. We argue that ZooWise addresses these aspects of learning with the use of specially designed tools aiming at scaffolding students' learning within three contexts: cognitive, social and epistemic.

For example, through the *Display* and *Evidence Pages*, the task introduces the students to the problem, the different sub-tasks and activities, provide explanation about what the next step will be, provide content information about the work of IUCN, the different categories and criteria of extinction and they also present information that could be used as data/evidence to construct scientific explanations. In other words, these kinds of tools address cognitive goals of learning since they have the potential to scaffold students' conceptual understandings about endangered animals and the evaluation criteria through engaging them in a process of evidence-based explanation construction. Moreover, through tools like *Show-N-Tell* that prompt students to create a presentation of their work and *Show all Work* which brings up all work that students have done so far in the project engage students in reflective and metacognitive practices, and also address cognitive goals of learning.

The epistemic goals of science are addressed through tools like the *SenseMaker*, which prompts students to make sense out of data and use those as evidence by placing them under an argument that they support. This tool scaffolds students' understandings about the epistemological aspects of science connected with evidence and its role in the construction of scientific knowledge. Likewise, specific *Wise Notes* address epistemic goals of science by presenting questions and starter prompts to scaffold students' in thinking about the validity of their explanations. In other words, through these prompts, students are asked to think about why and how they came to hold certain beliefs and understandings.
Lastly, the social aspects of science and social nature of scientific knowledge are illustrated through tools like the *Discussion Forum*, where groups of students are invited to communicate their evidence-based claims to other groups and engage in dialogues explaining the processes through which they constructed their claims. Social goals of science are also addressed through group work in which students engage in as they reason about data and jointly make decisions about what data count as evidence and collaboratively construct and communicate explanations to others.

There is ample theoretical evidence to support the assumption that the design framework that guided ZooWise has the potential to scaffold students in learning science and learning about science. However, the task is designed upon theoretical assumptions that ought to be applied and tested within the context of school classrooms. To address questions connected with the use of specially designed technology tools in support of science learning we frame a research agenda drawn from theoretical perspectives on model-based science, scientific inquiry, scaffolding, reasoning and argumentation. We retain that this research may advance our understanding of science and science learning in important and useful ways. The purpose of our research agenda is twofold and aims at: a) exploring the role of technology tools and specially designed tasks in scaffolding science learning through engaging in model-based reasoning; and b) examining the role of specific tasks in supporting the development of understanding about the nature of science and the work of scientists. Specifically, questions to be answered are:

- What is the nature/content of the evidence-based claims constructed by the students?
- What are the characteristics of the interactions/conversations within each group of students in the context of the evidence-explanation continuum?
- How do students reason about data and make decisions about 'what counts'?
- In what ways, if any, does the task support students' understandings about the nature of science and the work of scientists?

Next steps of our work will explore these questions in order to better understand the ways (if any) in which the task is designed supports students' understandings of science, about science and the role of evidence in the construction of scientific knowledge. We hope that this paper will provide the basis for conversations amongst educators, researchers and curriculum developers about the potential of specially designed web-based tasks to scaffold science learning through inquiry and support the development of contemporary understandings about the nature of scientific knowledge and the work of scientists.

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