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TOWARD A DESIGN FRAMEWORK FOR INTERNATIONAL PEER DISCUSSIONS: TAKING ADVANTAGE OF DISPARATE PERSPECTIVES ON SOCIO-SCIENTIFIC ISSUES

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This paper describes how we have adapted the WISE technology and curriculum for use in an international setting. We also report on a cross-cultural collaboration between the two authors, representing the WISE project in the U.S. and its counterpart, called Viten (see http://viten.no) in Norway. After introducing the WISE platform and describing our collaboration, we present a brief comparison of the Norwegian and U.S. educational systems. We then describe "Viten.no," the national level program that has grown around this effort. Next, we present our designs for a collaborative activity where students from our two countries first perform a WISE (or Viten, respectively) inquiry project concerning wolf populations and biodiversity, followed by a sequence of online discussions designed to capitalize on cultural and geographic differences for purposes of conceptual learning. Finally, we describe the outcomes of our classroom trials of this international curriculum, which are limited in scale but sufficient to allow the framing of some design principles. We close with a discussion of the implications of such curriculum, and our own current efforts to continue this line of research.

Keywords: International exchange; online discussions; technology enhanced learning environments.

1. Introduction

When combined with new understandings about science learning and instruction, the World Wide Web can enable exciting new possibilities for the science classroom. Research conducted using the Web-based Integrated Science Environment (WISE) project has investigated effective uses of technology in supporting student knowledge integration — a kind of learning where students build connections between new material and their existing ideas to create a coherent understanding (Slotta & Linn, 2009). WISE offers an innovative Web-based curriculum environment where middle and high school science students conduct design, debate, or critique activities using materials drawn from the Internet. The goal of these inquiry oriented curriculum projects is to promote a deep understanding of science concepts, to foster lifelong learning skills, and to integrate technological resources into the science classroom. WISE provides a library of curriculum projects that bridge disciplines and connect to local resources, making activities personally relevant to students. Embedded assessments within the project allow teachers to follow student progress, helping them to better understand how their students learn.

In this paper, we describe how we have adapted the WISE technology and curriculum for use in an international setting. Educators from several different nations have adopted WISE in order to enact inquiry activities for purposes of research (Kollar *et al.*, 2004; Scheepens & Slotta, 2002) or enhancing school science offerings (Slotta *et al.*, 2003a,b). In order to support such collaborations, the WISE team developed supports for the translation of WISE technology and curriculum activities (Slotta *et al.*, 2003a,b). However, our early translation efforts raised new questions about the ecological validity of exporting inquiry science materials developed for one national setting into other nations. Science curriculum frameworks differ widely between countries, as do the technological expectations of students and teachers. We should expect the effectiveness of our innovations to be deeply affected by those cultural variables. Thus, we review our progress in achieving a cultural translation of WISE, including the translation of curriculum activities that are concerned with socioscientific issues.

We also report on a cross-cultural collaboration between the two authors, representing the WISE project in the U.S. and its counterpart, called Viten (see http://viten.no) in Norway. From the outset, we have been attracted by the prospect of engaging students from our two countries in online discussions with international peers, with the notion that there can be some advantage to learning the science topics by engaging with others who have a distinct cultural or geographical perspective. Thus, we sought to develop some design principles for online discussions (and other curricular exchanges) that are productive in terms of science learning. It is not enough simply to connect students with peers from different countries for the motivational benefits (i.e. of having an international "pen pal"). Rather, there should be some real cognitive or sociocultural advantages that results directly from the fact that students are located in different parts of the world.

After introducing the WISE platform and describing our collaboration, we present a brief comparison of the Norwegian and U.S. educational systems. We then describe "Viten.no," the national level program that has grown around this effort. Next, we present our designs for a collaborative activity where students from our two countries first perform a WISE (or Viten, respectively) inquiry project, followed by a sequence of online discussions designed to capitalize on cultural and geographic differences for purposes of conceptual learning. Finally, we describe the outcomes of our classroom trials of this international curriculum, which are limited in scale but sufficient to allow the framing of some design principles. We close with a discussion of the implications of such curriculum, and our own current efforts to continue this line of research.

1.1. *The Web-based Integrated Science Environment (WISE)*

A substantial body of research has now demonstrated the benefits of asking students to make predictions, reflect on new and existing knowledge, assess their own progress, create arguments, design artifacts, and engage in collaborative debate (e.g. Driver, 1985; Brown & Campione, 1994; Scardamalia & Bereiter, 1996; Driver *et al.*, 1996; Vanderbilt, 1997; Bransford *et al.*, 1999; Kolodner *et al.*, 2003). Computer-based learning environments can scaffold students as they perform such activities, providing cognitive and procedural guidance and freeing teachers to interact with students about complex science topics (diSessa & Minstrell, 1998; White & Frederickson, 2000; Linn & Hsi, 2000; Slotta, 2004; Songer, 2006). Learning environments can also provide embedded assessments that capture students' ideas about science as well as their abilities to critique evidence or arguments, make predictions, and reach conclusions. Such data can then be accessed by teachers in support of formative assessment and feedback, and could even be used during class as a source of deep interactions concerning student ideas.

Since 1997, WISE has been under continuous research and development in order to provide such a learning environment for students and teachers, as well as to serve as a research platform for investigations of inquiry-oriented learning and instruction (Slotta & Linn, 2009). The design of the WISE technology, curriculum and assessments has beenguided by prior research in scaffolded inquiry (Songer & Linn, 1991), the role of online discussions (Hsi & Hoadley, 1997), the design of effective Web-based materials (Slotta & Linn, 2000), the effectiveness of different kinds of reflection prompts (Davis, 2004), and the design of controversy-based curriculum (Bell, 2004). WISE research has focused on an array of topics such as the use of social grouping and peer feedback in design projects (Cuthbert & Slotta, 2004), the design of simulation-based knowledge constructors (Clark & Jorde, 2004), the integration of models and simulations into inquiry projects (Varma *et al.*, 2007), and teacher practice and professional development (Slotta, 2004; Williams *et al.*, 2004).

WISE inquiry projects vary in duration from 4 to 10 class periods (45 minutes each), and address a wide range of topics found in middle and high school science. Typical projects engage students in *designing* solutions to problems (e.g. building a desert house that is warm at night and cool during the day), *debating* contemporary science controversies (e.g. Should wolves be protected as members of the forest ecology?), or *critiquing* scientific claims found in web sites (e.g. arguments for life on Mars). Wherever possible, WISE projects rely on "evidence" from the Web as

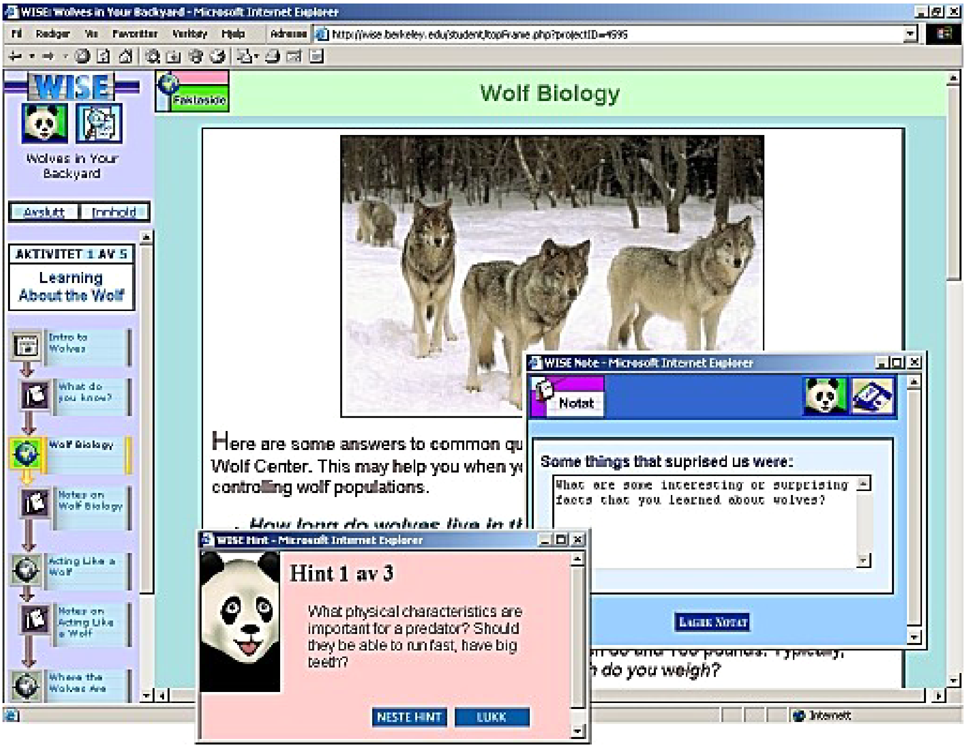

Figure 1. WISE student interface (left) showing the inquiry map, the content area, a notewindow, and the hints window.

resources, and focus on scientific problems or issues that are personally relevant to students.

Figure 1 displays the WISE learning environment interface, including the pop-up windows for reflection notes and cognitive hints. Students navigate through activity "steps" in the left-hand frame of their Web browser, called the "Inquiry Map." Each step in the project can result in the display of Web pages (e.g. for supporting student designs or debates), the WISE notes window, online discussions, or any one of numerous inquiry tools (e.g. Java applets for data visualization, simulations, and causal maps). As students work through the sequence of activities that comprise the project, the teacher circulates within the classroom, interacting with one small group of students at a time, helping them interpret Web materials, reflect on the topic and interact with their peers. More than 50,000 teachers and 250,000 students have registered for WISE since 1997.

The Norwegian project, called Viten[1] is supported by the Norwegian Department of Education and is based at The University of Oslo and The Norwegian

[1]The word Viten, in Norwegian, is a rough translation of the English word "wise".

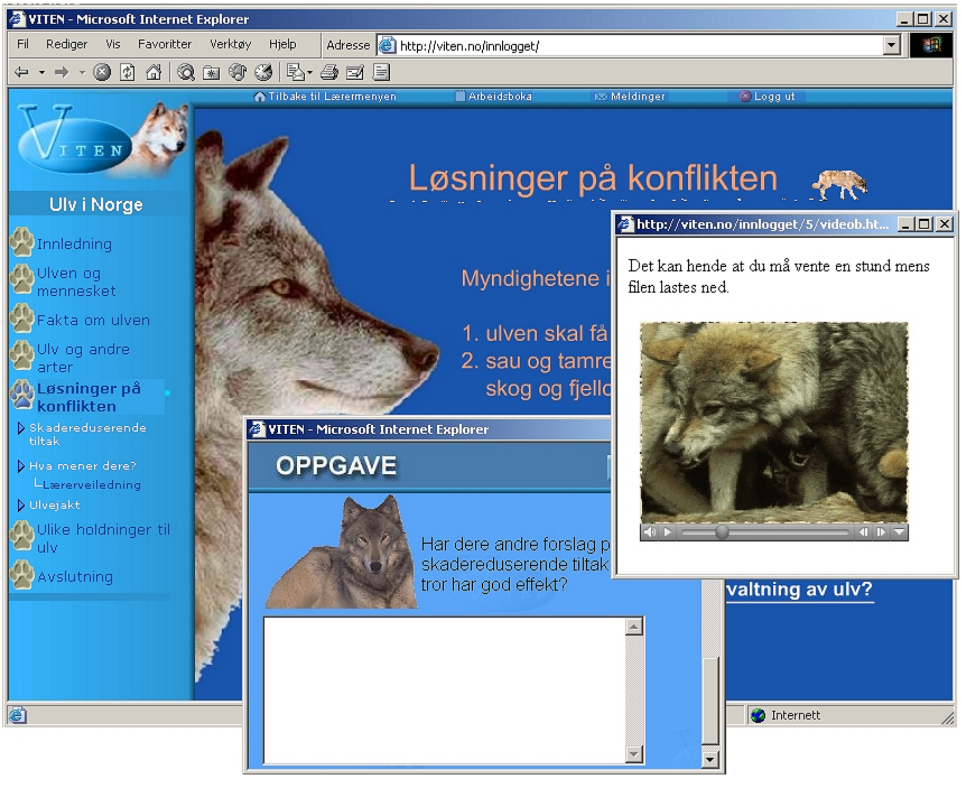

Figure 2. The Norwegian version, called Viten, also showing notes and hints windows.

University of Technology (Jorde *et al.*, 2003). Viten (Figure 2) has grown over the past decade, and has now been used by nearly half of Norwegian science teachers. It has also served as a platform for research by Norwegian science educators (e.g. Mork & Jorde, 2004). The next section of this paper reviews the trajectory of our collaboration, including a comparison of the educational systems, and a discussion of the adaptations that allowed Viten to adapt the WISE technology and curriculum for success within a Norwegian educational context.

2. A WISE International Collaboration

In 1998, the two co-authors of this paper began a collaboration to extend the WISE technology and curriculum to Norwegian secondary science instruction. We recognized that a technology and curriculum partnership between our groups could enable the exchange and co-design of innovations while allowing the evolution of culturally appropriate software and curriculum for each national setting. In particular, we were optimistic about the prospect of an open source development community, shared by the technologists in our respective settings. If we could employ the same core technologies and adapt only the surface features, user interfaces, etc., this could allow an economy of development. We were also interested in the opportunities for research, hoping to develop a framework for international exchanges between students in our two countries (conducted in English language). Ultimately, such research could contribute to our understanding of collaborative inquiry and socially constructed meaning.

Our collaboration began with a direct language translation of the WISE technology, as well as a curriculum project called "Cycles of Malaria" in which students compare three different approaches to controlling the disease worldwide (see Figure 2). Very early in our efforts, it became apparent that a simple language translation of platform and content would not be satisfactory for Norwegians teachers, students or researchers (Bell *et al.*, 2005).

In the early years of our collaboration, we interviewed two California 7th-grade life science teachers before and after they ran the Cycles of Malaria project, as well as four Norwegian teachers from the equivalent middle school level science course (Slotta *et al.*, 2003a,b; Jorde *et al.*, 2002). We asked the teachers to comment on the WISE technology platform as well as the Cycles of Malaria project (in Norwegian: "Kampen mot Malaria"), and to reflect on the challenges of adding inquiry and technology-based projects to their course. These interviews raised awareness about the differences between the educational systems in our two countries, and how those differences might impact the translation of innovative science inquiry materials from one to the other. In addition to language issues, we anticipated that cultural, institutional, political, geographical, and even geological differences might present challenges and opportunities for the Norwegian version of WISE.

Teachers from the two nations differed in their evaluation of the WISE technology. The U.S. teachers appreciated the step-by-step sequence of well-defined student activities. The two American teachers interviewed had never used WISE or any other technology environment, and were quite nervous about losing control of the classroom. As one teacher said, "When I see more than a couple of hands up in the air, I know that I won't be able to keep things in control for much longer — and then I might have to pull the plug on the whole thing." WISE offered these teachers a comfortable level of structure, in the sense that students using a WISE project always know what the "next step" is, and can be engaged at different paces and different levels of engagement.

In contrast, the Norwegian teachers did not think that the Norwegian students required as much step-by-step control of the software, and were not as concerned about losing control of the classroom. Rather, they commented that they would prefer a more substantial, open-ended and coherent task for students, such as a research report that was coordinated by the overall project. This was preferred over the piecemeal reflections, concept maps and online discussions and other bits of data collected form students in WISE Cycles of Malaria project.

Another difference between comments made by the U.S. and Norwegian teachers was in their preferences for certain technology features. The Norwegian teachers wanted a more interactive design than that provided by the WISE environment. The feeling of the Norwegians was that the content should be more "alive," with greater interactivity — such as pop-up quizzes and flash animations. They wanted content that would engage students more actively, whereas much of the WISE content was in the form of Web pages that students read and reflected upon. Finally, Norwegian teachers and researchers alike felt that WISE was a non-Norwegian product, particularly in its foreign name and the fact that some of the software interface had yet to be translated from English. While these features did not affect the functionality in any way, the "identity factor" was substantial, leading to discussions about creating an entirely new learning environment for Norwegian classrooms.

The interviews, based on our early language translations of WISE into Norwegian, informed our thinking about the design of a more appropriate platform for Norwegian schools. The next section of this paper offers a comparison of the two countries in terms of (1) their science curriculum; (2) the importance of inquiry within the curriculum, and (3) the use of technology in science classrooms.

2.1. *Comparison of educational systems*

Building on earlier work with the TIMSS project (Schmidt *et al.*, 1996a,b) that examined international differences in "Characteristic Pedagogical Flow" of various countries, we began to consider how a technology-based inquiry project designed for U.S. schools could fit within Norwegian ones (Slotta *et al.*, 2003a,b). The following sections offer a broad characterization of these differences in terms of curriculum, inquiry, and technology. These understandings, while certainly broad in scope, have informed our development of Viten.no and the corresponding inquiry curriculum for Norwegian schools. They also help us to understand the role of such inquiry projects within our respective countries, and how an element of international exchange might be designed.

2.1.1. *The science curriculum*

Norway has a relatively small population of about 4.5 million persons, and has thus been quite successful in maintaining a national curriculum in science and other disciplines, as well as a national plan for the implementation of Information, Communication and Technology (ICT) in the educational system for 2000–2003.[2] The Minister of Education stated the following in the introduction to this national plan (translation by second author):

> "*We are entering a new century where knowledge and learning will be the key to success, both at the individual level and for society as a whole. Knowledge and competency are the basis for growth and development in our society, even more than natural resources and*

[2]http://odin.dep.no/kuf/publ/2000/ikt/ (IKT i norsk utdanning. Handlingsplan 2000–2003).

> *industry. Information technology is one of the strongest forces in this development.*"

Over the past decade, the U.S. education system has also undergone an evolution of ideas and values relating to curriculum, largely in response to the recent legislation called "No Child Left Behind" (NCLB, 2000). Partly motivated by U.S. students' performance on international comparison studies (Schmidt *et al.*, 1996a), educational policymakers began calling for greater levels of accountability for students and schools, and formalized assessments were put into place throughout the United States.[3] Accordingly, science assessments have placed most of their emphasis on mastery of specific content standards, with a minimum of attention provided to inquiry skills such as design, experimentation, modeling, or critique of evidence. The U.S. science curriculum has been described as being a "mile wide and an inch deep" (Schmidt *et al.*, 1996b; Linn & Eylon, 2006), putting tremendous pressure on teachers to cover all the required topics in a given course.

The teachers in our two nations have been trained in very different educational systems. It is therefore no surprise that they exhibit different beliefs about science education and the use of technology. One of the most prominent differences was seen in teachers' perceptions about the role of central government or district authority in the determination of curriculum.

In Norway, there is a national curriculum that all teachers adopt, with considerable regularity and corresponding textbooks. The local government and school boards do help to customize this curriculum to make it personally relevant to students, and teachers do create some of their own activities. But overall, there is a sense that the curriculum is an important matter of national concern, determined at the national level.

In the U.S., teachers are accountable only to state curriculum standards, and typically have a great deal of flexibility in how they address those standards. The curriculum itself is informed by suggested textbooks, standards to be "covered," and rubrics that are handed down within particular school boards. Course syllabi are handed down from one teacher to the next, or created by teachers during their in-service days. This results in a great diversity of curriculum between schools even within the same local region, reflecting a stronger belief by teachers that it is their responsibility to create the curriculum.

2.1.2. *Inquiry and technology in the science curriculum*

In terms of their inclination toward project-based inquiry activities such as those offered by WISE, Norwegian and U.S. teachers had differing perspectives. In the Norwegian national curriculum, all science teachers are required to include project work as a way of getting students to synthesize their learning. While this national

[3] These are not national assessments, but rather are the responsibility of individual states to develop standardized assessments that adhere to explicit guidelines.

objective is favored by teachers, there are very few ICT based projects available to choose from. Thus, WISE (and later, Viten) was seen as a potential solution to this national curriculum requirement, given their focus on inquiry projects where students can pull their ideas together and make important connections to the science content. The Norwegian teachers we interviewed observed that the WISE: Malaria project fit meaningfully into the life science curriculum and "made a lot of sense."

In contrast, US teachers are not required to adopt project-based methods, which are sometimes seen as being "too in-depth" given the breadth of coverage required by American science standards. U.S. teachers have participated in WISE for a variety of motives (Slotta, 2004). Some have sought innovative curriculum approaches to improve their students' experience; some have sought ready-to-use supplemental materials to complement their instruction of core topics. Most teachers who have adopted WISE in the U.S. (now more than 10,000) have done so in order to integrate technology, because they feel it is important and motivational for students. However, because most U.S. science teachers feel that it is an exorbitant use of class time to spent a full week on a deep inquiry project, they have had varying levels of success in making WISE work effectively within their curriculum. One of our interviewed teachers said, "There's no way I can justify spending a whole week on Malaria control, when I usually only spend two weeks covering my whole disease unit!"

Teachers from both countries have good levels of access to Internet technology. However, the barriers presented by the heavy content expectations (in the U.S.) and the lack of suitable ICT based curriculum (in both countries) have resulted in mostly superficial uses of technology in the science classroom (Becker, 1999). While U.S. teachers are more experienced with technology relative to their peers in other countries, they tend to focus their use on "basic skills," such as the use of productivity software, and "drill-and-kill" preparations for standardized exams (Schmidt *et al.*, 1996b).

2.2. *Viten: A new Web-based learning environment for Norway*

While the Norwegian teachers interviewed in our early translation phases were successful in running the Malaria project in their classrooms, several key issues came out of this initial effort (Jorde *et al.*, 2002; Slotta *et al.*, 2003a,b). First, the user interface was not satisfying to Norwegian researchers or teachers, not only because of the few remaining English language elements, but for many small and sometimes intangible reasons: from a design perspective, it just didn't "feel" like a Norwegian environment to them. Second, the media format of materials was not sufficiently rich, dynamic and interactive. Third, the WISE curriculum was too "structured" for the tastes of Norwegian teachers and researchers, who wanted more open ended and coherent project structures. Finally, there was the issue of building a Norwegian identity for the technology platform and curriculum content. Some of these issues could be addressed by improving our translations of the WISE technology, or even building a separate interface for WISE-Norway. However, at the heart of the matter was the need for autonomy and clear Norwegian identity, which would allow the Norwegian researchers to prepare materials that were distinct from those of WISE, as well as new kinds of features that might have been difficult to add into WISE.

This story could have gone quite differently from this point, if the WISE software code had been sufficiently well structured (i.e. with the user interface code being maintained separately from the other functionality), and sufficiently well documented that another group could have taken the code and made good progress in developing their own derivative system. Ideally, the WISE team would have provided the Norwegian group with a copy of the WISE code, and let them move forward with their own differentiated version. Improvements and extensions made by either group could then have been shared with the other, and the technology staff from both groups could have been strengthened by close affiliations in a technology community. Unfortunately, WISE was still in fairly early stages of software development, and the code base was simply too messy, and its user interface too convoluted with the other functionality for it to be adopted or adapted by the Norwegian developers.

Thus, the Norwegian team decided to build its own system from scratch, guided heavily by the WISE functionality, but addressing all the issues named above: a new, colorful user interface, completely in Norwegian language, with more functionality for flash technologies and other interactive content, and — most importantly — a software system built by Norwegians for Norwegians. Known as Viten (see http://viten.no), this system looks and feels quite similar to WISE (see Figure 1 above), and has enabled our collaboration to proceed while allowing the Norwegian group to conduct its own autonomous developments of technology and curriculum. The "made in Norway" label of Viten has also likely helped the project gain support from the Norwegian Ministry of Education and gain credibility across Scandinavia and Europe. Perhaps most importantly, it has allowed two research groups (University of California, Berkeley, and University of Oslo) to proceed with similar technology environments that are well suited to their own cultural contexts, allowing for parallel and even intersecting research programs.

2.2.1. *A better fit for Norway*

Viten was launched in 2001 with a small library of three curriculum projects: A revised version of the Malaria curriculum, a new project called "Radioactivity" in which students were introduced to a scenario of a radioactive waste spillage, and guided through steps (in a Flash interface) of measuring and evaluating the severity, and a project called "Wolves in the landscape" that was first developed in WISE (where it was called "Wolves in Your Backyard") but then translated and adapted to Viten.

Mork and Jorde (2004) studied the implementation of the Viten wolf project in two Norwegian science classrooms with students aged 14–15 years. Just as reported in the WISE research (Slotta, 2004; Slotta & Linn, 2009) this study recorded significant learning gains in all relevant content areas using a pre-post test method. Such gains would be expected from any week-long curriculum that emphasized a deep treatment of science topics. Still, it is important to measure student learning outcomes, and Viten researchers demonstrated significant pre-post gains, including a measure of retention after 4 months. This study also found that the Viten project helped two thirds of students change their attitudes about wolves, as measured by pre-post interviews (Mork & Jorde, 2004; Jorde & Mork, 2007).

Since these early research trials, Viten has become the primary source of Web-based inquiry science projects for students in Norway, at every middle and high school grade level. The project has matured into a success story, offering a small library of approximately 20 well designed inquiry projects — some descendants from earlier WISE versions, but most created exclusively by Norwegian educational content developers. These projects have provided an important resource internationally, as they are now translated into other languages, including English! It is estimated that more than half of all science teachers in Norway have now employed Viten, as well as many teachers in Denmark and Sweden. In 2006, more than 2500 teachers used Viten, with 70,000 students. In addition, several educational research groups in Norway have been able to use Viten as a platform for their own investigations (e.g. Jorde & Mork, 2007; Ludvigsen *et al.*, 2003). Thus, the Viten technology platform has clearly been well suited to the Norwegian context.

Viten and WISE have continued to co-exist and evolve side by side, with periodic papers and presentations written jointly by researchers from the two groups (e.g. Slotta *et al.*, 2003a,b; Bell *et al.*, 2005). In some ways, the lack of any specific technology collaboration has been fortuitous. Because we were no longer dependent on any common technology resource, we found our exchanges to be more concerned with high level concepts, as related to the design of curriculum, the use of new media like flash, and the issues related to eLearning standards (Berge & Slotta, 2006). Indeed, the maintenance and development of two distinct platforms has been a source of insight about the higher level issues and challenges that will confront such efforts over the longer term. WISE and Viten have now entered together into a wider community of researchers who see the potential of networked learning environments (Ludvigsen *et al.*, 2003; Bell *et al.*, 2005, and other papers from this issue). At present, this community is generally engaged with issues of re-use, interoperability, content and technology standards, emerging technologies (e.g. Web 2.0, social technologies, and semantic aggregation), and pedagogical models for inquiry and collaborative learning (Slotta, 2010).

At the turn of the millennium, WISE and Viten researchers were just entering this community, and their investigations were focused on the basic structures of inquiry projects and the role of technology-enhanced learning environments in K-12 science classrooms. One new opportunity arose from the fact that we were both actively engaged in classroom studies using similar materials and approaches: that we might connect students from our two parts of the world in meaningful curricular exchanges. It occurred to us that the Web-based environments (WISE and Viten, respectively) could support classroom-based activities in each location, providing locally contextualized activities, and preparing students for subsequent international exchanges. The next section of this paper presents the formative efforts in such a collaborative effort, from which we have learned a great deal and moved forward into new phases of the work. We describe our design process, review the resulting curriculum materials, and present the outcomes of our initial curriculum enactment.

3. Designing International Peer Exchanges

We sought to use the WISE and Viten learning environments to engage students with locally relevant "socioscientific issues," followed by structured interactions with international peers that were designed to capitalize on "productive differences" in terms of culture, geography, and educational systems. We began a research program that would investigate the design of such activities, including how to assess their impact, and how to employ technology scaffolds for a variety of peer exchanges and collaborative activities (Slotta, 2009). In this section, we summarize our pilot study, which engaged U.S. and Norwegian students in WISE and Viten projects, respectively, followed by a small set of international discussions.

Our first design principle is to *select a topic that is important to the science curriculum in both countries, and that fits well within an established inquiry context.* We began by selecting a topic that was already addressed by existing WISE and Viten libraries: that of wolf management, which is an important socioscentific issue in both the U.S. and Norway, yet with differences that might allow for productive discussions between students. The two countries differ with respect to this issue, primarily because of the vastly different numbers of wolves in the two countries, with thousands in the U.S. (connected to many more thousands in Canada) vs. only a dozen or so in all of Norway (connected to a slightly larger population in Sweden). One important facet of this issue that appears regularly in the popular press in both countries has to do with the killing of livestock by wolves. Policymakers, environmentalists, farmers, agricultural officers, and hunters maintain an ongoing debate about the importance of wolf populations, and the best strategies for wolf management, with arguments often focusing on the biological issues related to the role of predators in an ecosystem.

Wolves are top predators in a forest ecosystem, and therefore play an important role with respect to biodiversity. The top predator in any ecosystem will tend to eat the most abundant prey, keeping its population under control. Removing the top predator from an ecosystem tends to allow its normal prey to proliferate unchecked, resulting in devastating consequences for the other animals in the food chain, as well as the plants and ultimately the overall habitat and ecosystem. In the northeastern U.S., for example, the elimination of wolves has allowed the proliferation of deer populations. Millions of deer now flood the forests, eating all the young trees and other vegetation and dramatically affecting many other plant and animal species (Stolzenburg, 2008).

Thus, the important issue of wolf management offers a good connection to life science concepts relating to the role of top predators in ecosystems and biodiversity. Because of the interesting science connections to this important social issue, and the undeniably charismatic animal, researchers in WISE created the project titled "Wolves in Your Backyard" where students apply science knowledge to critique various perspectives about the issue. The Viten group had followed with its own translation of this project, titled "Ulv i Norge (Wolves in the Landscape)."

Our approach was therefore to deliver these pre-existing wolf management projects to students in their own language, followed by carefully designed English language discussions, delivered in the WISE environment. Fortunately, Norwegian students are sufficiently fluent in the English language that they can exchange in online discussions with U.S. students.

Our second design principle is to *determine online discussion topics that capitalize on differences between the two countries regarding the issue, with a focus on the underlying science*. In other words, while we could design engaging discussions that focused on the cultural differences in relation to the curriculum topic, this design principle requires that discussions focus on the scientific connections to the issue.

We identified two "key concepts" relating to the wolf management issue where U.S. and Norwegian students could bring productive differences to bear in their discussions: First, Norwegian students appeared to have substantially greater experience and sensitivity to the concept of global interdependence than the U.S. students. Norway is a small European country, and yet is heavily invested in issues of global climate, oil exploration, international economics, etc. In contrast, U.S. students living in northern Minnesota experience very little direct exposure to issues of global interdependence. A second key concept was that of biodiversity in forest ecosystems, to which the U.S. students appeared to have a greater depth of understanding and sensitivity — presumably because of the rich forest ecosystem in which they reside. While more than 2000 wolves roam the Minnesota forests (one of the world's largest wolf populations), only a small handful of wolves populate Norway, and are not a major factor in any ecosystem there. Table 1 shows the two discussion topics that we designed to try to leverage those differences for purposes of helping students develop a deeper insight into the science of wolves, predators and prey, and the importance of such ecosystems to the wider global context.

We hypothesized that students from the two countries would differ in their initial understandings of the two key concepts, and that these differences would be reflected in students' explanations of pre-test items. It was further anticipated that the online discussions, because they connected students with peers who held distinct perspectives about the topics, would help all students expand upon their understandings. Such gains in understanding could be measured from the content

Table 1. Discussion topics used to address the two key concepts.

Discussion topic 1 (key concept of biodiversity)
Why are wolves important to the ecosystem? What do they contribute to the health of their environment? What plants and animals benefit from the presence of wolves?
Discussion topic 2 (key concept of global interdependence)
Let's discuss the global importance of wolf preservation. Why is it important to protect an endangered species like wolves, even if they don't live in your country? For example, there are no wolves in Japan, so why should Japanese students worry about the preservation of wolves in Norway or the U.S.?

of discussion comments as well as improved explanations on pre-post test items. We organized a trial of this approach using two volunteer classrooms, who overcame some procedural and logistical challenges, including time zone differences as well as scheduling problems. Below, we discuss the outcomes of this initial trial.

3.1. *A study of peer exchange between U.S. and Norwegian students*

Subjects were 30 sixth grade students (age 12) from a midwestern U.S. classroom, and 22 tenth grade students (age 15) from a Norwegian classroom. The different age groups of these samples was partly because the WISE wolf project was written for middle school age students, and the Viten wolf project was written for junior high school age. However, this turned out to be a helpful circumstance, as the English skills of Norwegian high school students allowed them to participate more fluently in the English language discussions.

In the first phase of the trials, students worked only with peers in their own classrooms and language to conduct the WISE or Viten wolf project, respectively. Students in both countries succeeded quite well in this phase, supported by the well-designed curriculum materials and technology scaffolds of their respective learning environments. The second phase of the study focused on the online discussions between students from the two countries (listed in Table 1), including some additional orientation activities. All international exchanges were asynchronous (there was a 7 hour time difference between the two classrooms), with students from the each nation adding comments during their school day, and returning the following day to find new comments that had been added by their international peers overnight.

In order to provide students with a common technology platform for the discussions, we designed a new "mini-project" using WISE, where students from the two nations could interact with one another in online discussions in English. This mini-project consisted of five sequential activities (see Figure 3). In the first activity, students introduced themselves to their international peers, saying a few words about where they live and their favorite hobbies. Next, students conducted a pre-test concerning their beliefs about the two key concepts. Third, they participated in an online discussion concerning the importance of biodiversity (the first key concept).

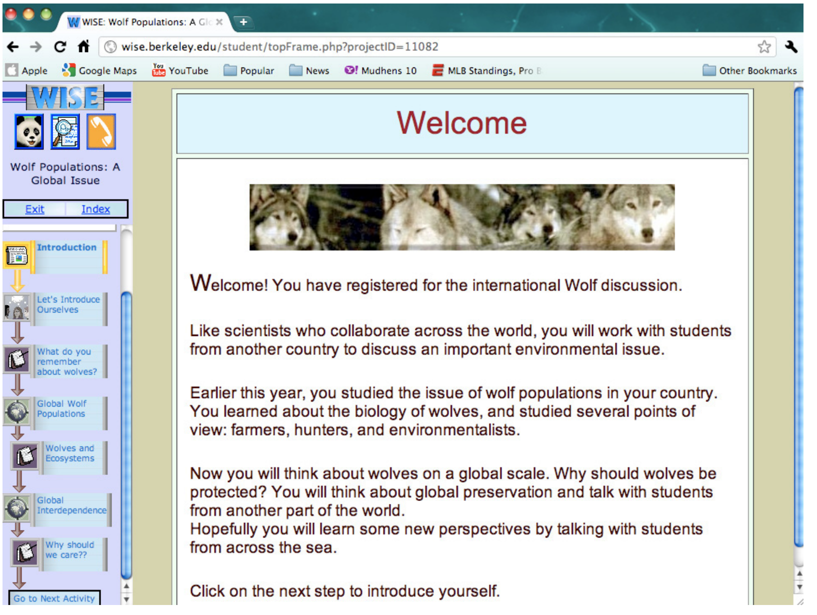

Figure 3. "Wolf Populations: A Global Issue", a WISE Mini-project, was created to host online discussions and capture pre- and post-test responses.

Fourth, they participated in an online discussion concerning the nature of global interdependence (the second key concept). Finally, students completed a short post assessment to determine whether their international exchanges had affected their beliefs about the key concepts.

Because students were arriving at this mini-project from somewhat disparate points of view (e.g. the Minnesota students had completed the WISE "Wolves" project several months prior to this international phase, whereas the Norwegian students had only just finished the Viten "Ulv" project), the pre-test items were designed to include an aspect of review and orientation to the mini-project. Thus, the mini project began with a short review of the basic science of wolf ecology, and an introduction of the two key concepts, with pre-assessments as described in Table 2.

Post-test items were designed to capture any changes in the emphasis of key concepts that might have emerged as a result of the online exchanges. Table 3 shows the post-test items, which were delivered as simple assessment items (i.e. a question prompt with a text box for students to complete their explanation).

3.2. *Findings and discussion*

3.2.1. *Pre-test explanations*

Pre-assessments of student ideas about the two key concepts were consistent with our hypothesis about the initial differences between students from the two countries.

Table 2. Pre-assessment items, including orientation materials.

Key Concept:	Biodiversity in Forest Ecology	Global Interdependence
Review materials	The following two links will help you understand what is happening with wolf populations both in Norway and the United States. As you look at each of these sites keep in mind the similar and different issues that are faced by each area.	Let's think about the interdependence of ecologies in different countries. Problems in one country can have important impact on people living far away. Many issues cut across international borders: global warming, fishing, mining, pollution, and others. But what about species extinction? Why should students in Japan care if the wolf disappears from Norway or the U.S.? To explore this issue, let's think about the Tiger — a species that will likely go extinct within 100 years. There are several reasons for this. First, their jungle habitat is being destroyed by many different forces (human expansion, logging, pollution). Second, they are being continuously hunted for their skins and for purposes of Asian medicines (their organs and claws are used for different medicines). Here is a short Web site that discusses Tigers. As you read the web site, think about why students in your country should care about the tiger's extinction.
Pre-assessments	Why are wolves important to the ecosystem? Be as detailed as you can!	Why should students living in Norway or Minnesota care about saving the tiger, who lives in the wild jungles of far away continents? Give specific reasons and think about ecology and global interdependence

Table 3. Post-test items that were included as a culminating activity within the "Wolf Populations: A Global Issue" mini project.

1. Why are top predators like wolves important to their ecosystem?
2. Why should people in one part of the world be concerned about saving species in another part of the world?
3. What is one thing you learned about wolves from reading the comments of students from the other country?
4. Why is it important to exchange ideas with students from other parts of the world?

When explanations were coded for the presence of the two key concepts, a greater percentage of the comments made by U.S. students emphasized ideas about biodiversity than did those of the Norwegians (see Figure 4). Likewise, the pre-test explanations made by the Norwegian students favoured ideas of global interdependence to a far greater extent than those of their U.S. peers.

While the number of participants was small and there were several elements of this study that made it difficult to conduct controlled comparisons (i.e. different

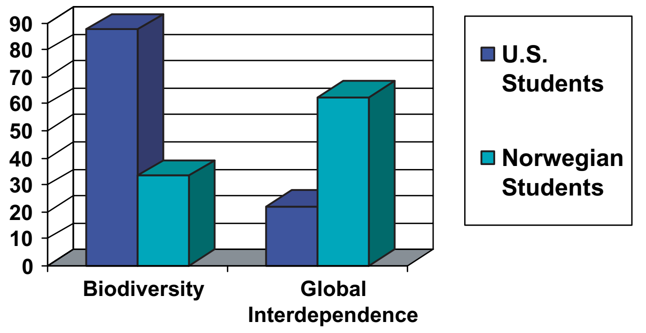

Figure 4. Percentage of pre-test explanations containing each key concept.

age levels, language skills, and curriculum focus), this pattern of explanations is consistent with our conjecture that students from the two countries differed in their initial understandings and sensitivities to the key concepts. Even after they had conducting a week-long WISE or Viten curriculum about wolf ecology, students appeared to hold different values in responding to the questions such as "Why are wolves important to the forest ecology?" as illustrated by the two responses below:

> "*because it is a part of our nature. so that it should be saved for our next generation so that they can study it and know about it.*"
>
> – Norwegian Student

> "*they keep the natural balance of things. If we were to kill all of the wolves and all of the other predators the ecosystem would be very unbalanced. The predators eat until food is less ubundant (sic). Then the predators die off so the deer, elk and other things grow more populated and this will happen forever until we dusturb (sic) the equilibrium.*"
>
> – U.S. Student

3.2.2. *Online discussions with international peers*

In the online discussions, Norwegian students made more substantive contributions (as measured by the average number of words per comment) in the discussion about global interdependence than they did in the discussion of biodiversity. The U.S. students showed similar asymmetrical participation in the discussions, measured by average word count, where more of the U.S. students made contributions to the biodiversity discussion ($n = 25$) than the interdependence discussion ($n = 13$), and 12 U.S. students made multiple entries in the biodiversity discussion, where none made more than one entry in the interdependence discussion. Thus, U.S. students engaged more within the discussion of biodiversity. While there were an insufficient number of comments to conduct a formal content analysis (Chi, 1997), the qualitative

Table 4. Sample comments from initial discussion of biodiversity.

Discussion topic: *Why are wolves important to the ecosystem? What do they contribute to the health of their environment? What plants and animals benefit from the presence of wolves?*
U.S. student 4: they are important because they effect (sic) the food chain. If they went extinct it may not effect (sic) us now but it could effect us later.
U.S. student 5: wolves are important because they keep animal populations down so they don't overpopulate eat all the food and starve.
U.S. student 7: Wolves are important to the ecosystem because they help preserve the balance of nature. They help contribute to the environment by killing the anamals (sic) that eat all the plants. Basically all plant life benefits from wolves.
Norwegian student 5: Wolves are an important part of the ecosystem. If you take away the wolf, the balance would be ruined. We mean that humans don't have any rights to kill the wolf or any animal. If the big issue is that the wolf kills many sheep, why don't we kill the wolverine instead? It kills and eats more sheep than the wolves . . .
Norwegian 3: We think that wolves are very important for the ecosystem. They hold the ecosystem in balance. They don't eat plants and it is good because we get medicines from the plants. Wolves are a very nice animal and they haven't killed anyone for 200 years in Norway. They don't harm us if we don't harm them. We think that the wolves should be protected.
Norwegian 6: we shouldn't keep wolves, I wish them being elimenate (sic), because they will be more then they 're today. which says they will kill/eat us.

nature of comments made by students were noticeably asymmetrical. Table 4 contains a sample of student comments from the discussion of biodiversity, illustrating the opportunities for Norwegian students to gain more detailed ecological argument from their U.S. peers.

Despite the apparent qualitative differences, it must be pointed out that the overall level of engagement in these discussions (i.e. the number of words and distinct comments added by students) was not sufficient to constitute a meaningful exchange of ideas or growth of shared understanding. These limited data were due mainly to the logistical challenges of orchestrating this event at such a distance, between schools, with teachers who had never done anything like this before. In the absence of formal analysis, we can infer from these measures that students from the different countries illustrated disparate ideas, and that this activity exposed them to those disparate ideas from their international peers.

3.2.3. *Post-test explanations*

The disparate pattern of student explanations observed in the pre-test is substantially reduced on the post-test, as students from the two countries appear to employ ideas from both key concepts in more equal measure (see Figure 5).

While not statistically significant (due to the low number of comments per participant) this pattern of pre-post differences suggests an increased level of attention given by the U.S. students to ideas of global interdependence, and a similar increase by Norwegians in their consideration of biodiversity and ecosystems. Examples of

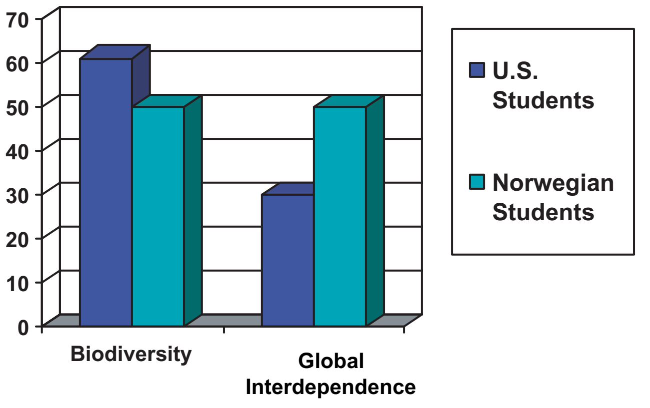

Figure 5. Percentage of post-test explanations containing each key concept.

Table 5. Sample responses to post-test item concerning global exchanges with peers.

<u>*Post-test Question*</u>: *Why is it important to exchange ideas with students from other parts of the world?*
"*It is important because the ecosystem is a part of the whole world. If we exchange ideas with them then we get good solutions about the wolves problems. We can also learn about the wolves problem in other parts of world. We can also have a good relationship with other countries which has the same problem like us.*" – Norwegian Student
"*It is important because that's one of the only ways to truly get the ideas of people from another country. We can also get a lot of new ideas and information you can't get out of a book.*" – U.S. Student
"*It is important so you can get a different (sic) viewpoint on everything so that you can understand that the problem doesn't just affect you and one sulution (sic) in America could wreck the sulution (sic) in Norway or another country.*" – U.S. Student

student responses to post-test items concerning the value of international exchanges are shown in Table 5, illustrating some promising trends in student ideas.

While the data reported here can only illustrate an apparent qualitative shift in student conceptualizations, they also serve to demonstrate our implementation of the two design principles, and suggest promising trends in the content and patterns of participation amongst students from our two countries. The effort to synchronize two classrooms in terms of their curriculum focus and availability for discussions was not trivial, nor were the obstacles of technology access and performance (i.e. internet connectivity for classroom computers) and teacher buy-in. Because of these eventualities, a replication of this study (which would surely result in more robust data, etc.) has yet to be performed. Thus, we have decided to go forward with our summary at this point, even though the findings lack empirical strength, because we fee that the narrative is worth telling, and we are hopeful about a new program of research that will build upon this foundation. The following section of the paper discusses these challenges further, and outlines our own plans for further research on international peer exchanges.

4. Conclusion

Our decade-long collaboration has included visits, sabbaticals, shared development of curriculum and technology, writing and presentations. Through such activities, we have each developed a deeper understanding of learning and instruction in the other's country, as well as our own. Another positive outcome is that the WISE and Viten technology platforms and curriculum frameworks are both stronger and poised for evolution in coming years. Thus, our collaboration has embodied the very principles we hope to capture in our program of international exchanges for science students: through meaningful exchanges with international peers, we have developed a deeper understanding and growth of perspective.

This paper began with a description of the differences between the U.S. and Norway with regard to science education, the integration of educational technologies, and students' ideas about socio-scientific issues. We then proposed two design principles to guide the creation of inquiry curriculum where students engage in international exchanges. We followed those principles in creating a short inquiry project to engage students in online discussions, and capture their pre- and post-ideas. Results of the pilot study, while somewhat more sparse (i.e., in terms of level of student contributions and exchange), suggest that there were some differences in the ideas brought to the experience by students from our two countries, and that the exchange may have helped students to add new ideas or emphasize previously subordinated ones within their conceptualizations. Teachers, while a bit frustrated with the technology, logistics and timezone differences, acknowledged that the students benefited from this activity, and agreed that it would go more smoothly and that students would be more engaged in a second iteration. Certainly the principles, materials, and pilot results reported here could inform the design of new research studies, and we hope that this paper can serve to inspire and inform such efforts.

This research has demonstrated the possible benefits of the two design principles, and suggests a more general strategy of designing exchanges according to "productive differences" that are determined by an initial analysis of the various settings and populations. Following this kind of approach, we have continued to make progress in our designs of international student exchanges. At present, we are developing an international community of students in discussions of global climate change, a topic well-suited to the approach of capitalizing on geographical differences. We are examining how students in China, Canada, Norway can exchange perspectives on global climate change that depend on their local geographical conditions and cultural frames. We continue to employ technology environments to scaffold a richer array of exchanges — particularly new social networking technologies and new media (e.g. wikis) for multi-user activities that emphasize the co-construction of knowledge and the value of social exchanges. To that end, we have developed a new technology for student exchanges, using a Drupal platform (http://drupal.org) that complements the WISE and Viten climate change projects. If global climate change is "the new sputnik" that will drive a generation of progress in science education, then we are hoping to define the next "space race" as an international cooperative endeavor. Researchers can and should exchange and co-develop materials, technology frameworks and ideas, and students should be engaged with one another in cooperative activities as well. This is not an easy process, and will require support from a community of scholars, technologists and educators.

Several logistical and pedagogical challenges must be addressed for such a program of research to progress, including language issues, technology capacity, curricular flow within any participating schools, and the variation in educational standards and expectations. Our current endeavors aim to provide a stronger empirical study that demonstrates the benefits of international peer exchanges on conceptual understanding and other aspects of learning (e.g. argumentation, design or collaboration). Additionally, we will continue to examine the relationships between educational systems, pedagogical flow, and student learning. We will develop curriculum that includes more sophisticated models of exchange, such as the pairing of international peers based on their previous project work, or creating semantic maps that guide students into relevant sub-groups. Online discussions may be used to inform a broader curriculum (i.e. rather than serving as a capstone) leading into deeper patterns of exchange and cooperative activities. While this paper has presented the first steps in our international collaboration, we are enthusiastic about the journey that stretches out before us.

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