THE AMNH *SEMINARS ON SCIENCE* PROJECT: LESSONS LEARNED FROM PHASE I 1999-2002

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In 1999, the AMNH launched an ambitious effort to create on-line science courses for K-12 educators that would immerse them in exciting science topics and give them access to the scientists and scientific expeditions of the AMNH. This project, called Seminars on Science, has completed a four-year phase of research and development in which 8 new science courses were created and taught on line. We at Inverness Research Associates have been studying the SOS project since it began, both to give formative feedback to the project and also to help portray the work and potential of the project to others.

In this paper our purpose is to capture the lessons learned from this initial phase of the SOS project. We address these questions:

- What is distinctive about the SOS course model? In what ways does this model have potential to address important problems in education?

- In what ways have SOS courses enhanced teacher knowledge and classroom teaching? What is their potential to make further contributions to science teachers and science teaching?

- What can we learn about the approach has the AMNH taken in developing the SOS project? How might this approach serve as a model for others engaged in educational innovation?

We believe the lessons learned from this project are relevant and of potential value to people in a wide variety of education institutions -– both formal and informal — who are interested in generating teacher knowledge and excitement about science in schools – and, ultimately, in enhancing the teaching and learning of science.

I. BACKGROUND

The SOS Project

The Seminars on Science project of the AMNH aims to offer educators science courses that 1) draw from the unique resources of the AMNH, 2) provide opportunities for teachers to learn science, and 3) can be produced in vibrant format in an online setting. The courses are produced and managed by the museum's National Center for Science Literacy, Education, and Technology (NCSLET), whose mission is to create Museum programs and products that bring the Museum scientists, their research, and the exhibitions beyond Museum walls.

The courses

Thus far the Seminars on Science project (SOS) has created and offered eight online courses[1]:

Figure 1.
Course offerings

	N of times offered
Dinosaurs among Us: the Link to Birds	2
Diversity of Fishes	5
Earth Inside and Out	4
Genetics, Genomics, Genethics	4
How to Think about Life in the Universe	4
Sharks and Rays: Myth and Reality	2
The Study of Spiders	4
Why are There No More Wooly Mammoths	2
TOTALS	27

Each course includes lectures, assignments, resources (including texts, web links, and videos) opportunities for reflection and communication with other learners

[1] A ninth course on physical science is being developed in conjunction with a new hall on Einstein. It will be offered for the first time in spring 2003.

and course leaders, and a final project. (See Appendix A for brief descriptions of the courses and the key concepts and processes each course addresses. We describe the shared features of the courses throughout this paper.)

Two-hundred and seventy-one people have completed courses for credit, and another 131 have audited the courses.[2]

The evaluation

The AMNH contracted with Inverness Research Associates to evaluate the SOS project. The purposes of the evaluation are both to provide formative feedback to the staff; to report summative findings to the project leaders and the funder; and to generate lessons learned for the field.

In evaluating the course development phase we:

- gathered resources to inform initial design decisions and offered feedback on initial design ideas
- evaluated each round of the initial offerings for formative purposes, and gave detailed formative feedback after each round to contribute to revision
    - studied all perspectives (scientists, course producers, learners)
    - critically reviewed course design, structure, content, learner participation
- surveyed and interviewed learners about the impact on their teaching.

We collected information through literature reviews, focus groups, phone interviews, mid-course and end-of-course on-line and email surveys, participant and expert reviews of courses.

On an annual basis, we provided detailed formative feedback, including critical reviews of courses, to the staff. We also prepared formal progress reports.

For this paper we also asked an independent reviewer from Metacourse, Inc., an eLearning design and consulting company, to review one of the courses to offer an additional outside perspective on the design features of the AMNH courses in the context of other efforts to provide learning opportunities at a distance to science teachers. The full report is attached as Appendix D.

[2] See Appendix B for further information about course enrollment.

This paper

In this report, we present summary findings and lessons learned from our study of the four-year development phase of the project. This paper is not intended as a full summative assessment of the project to date, nor does it address issues related to how schools and preservice providers might use the courses, as that potential usage is the focus of the next four-year phase of the project. Rather, it is a reflection on and synthesis of lessons learned from the initial development phase as they are relevant to the field.[3]

We first discuss SOS as a model that, in distinctive and important ways, addresses problems at the intersection of three domains: professional development, online learning, and the role of science-rich institutions in supporting reform in education. We then document the contributions of the courses to participants. Finally we reflect on the careful design process that the SOS employed in order to create these courses and propose that it may serve as a model for others who would undertake similar experiments.

[3] We have written many reports for the project over the last few years. Interim reports are available from either AMNH or Inverness Research. We are sampling from these reports, as well as drawing upon additional data we have collected, to illustrate and exemplify points in this report.

The AMNH at a glance

Founded in 1869
Its mission: to discover, interpret, and disseminate information about human cultures, the natural world, and the universe.
Its diverse activities include: field exploration and scientific research, innovative exhibitions, pioneering educational programs, and dedication to scientific literacy, making it a leader in addressing the issues that affect our daily lives and the future of the planet and its inhabitants.

In Science, the Museum is dedicated to exploring and understanding human cultures, the natural world, and our universe with:

- 47 curators and a scientific staff of over 200
- 70 postdoctoral and graduate fellows
- 32 million specimens and artifacts
- 2 “state of the art” molecular laboratories
- Over 100 research expeditions each year to all parts of the world
- One of the largest natural history libraries in the Western Hemisphere

Education at the Museum focuses on increasing scientific literacy among both adults and children in New York City, nationwide, and around the world, by sparking curiosity, providing information, and supporting exploration and investigation of scientific issues, through:

- Outreach to hundreds of thousands of schoolchildren and thousands of teachers on site and millions of schoolchildren and hundreds of thousands of teachers across the country
- Special programs and classes focusing on key scientific issues and concepts and cultural perspectives for audiences of all ages
- Over 150 lectures, films, performances, demonstrations, and workshops for children and adults annually
- The National Center for Science Literacy, Education and Technology, bringing the Museum’s vast educational resources and expertise to people around the nation and the world

Permanent and special Exhibitions interpret key areas of science for the public and serve as a field guide to our planet, its cultures, and its place in the universe, through:

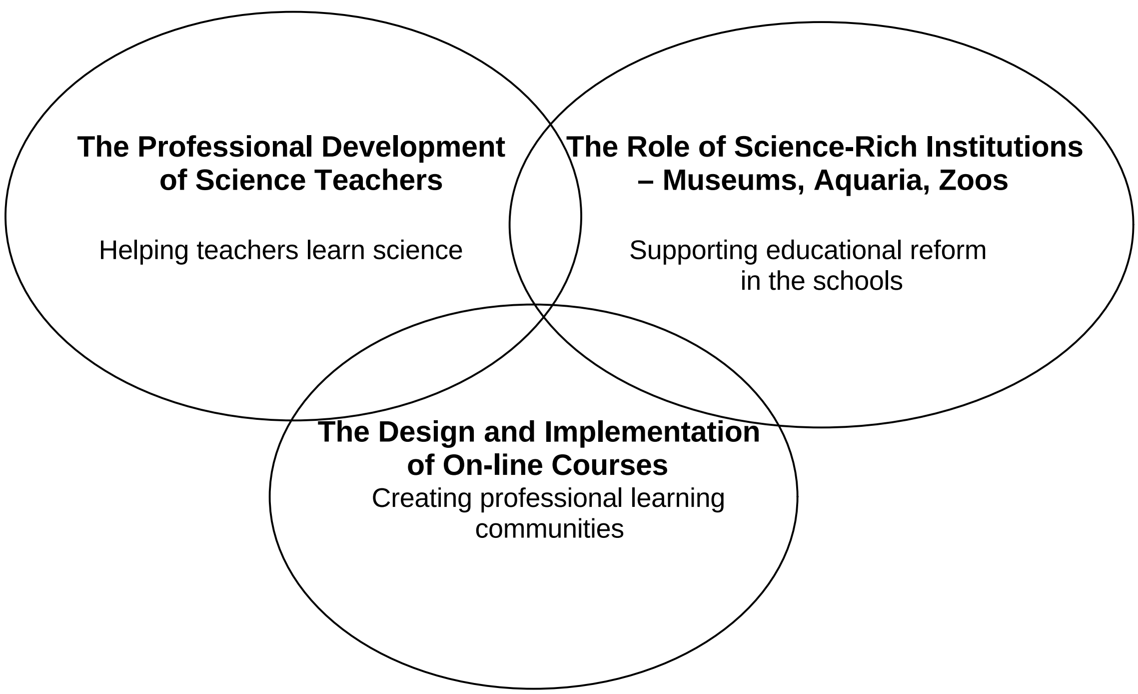
- Exciting temporary exhibitions exploring important contemporary cultural and scientific issues in depth
- 45 permanent exhibition halls, 13 of which have opened in the past 10 years
- Cutting-edge and innovative exhibition technology
- In-depth analysis of scientific issues

(Source: AMNH Visitor Brochure [updated by staff to reflect current resources and programs]. Additional information is available at http://www.amnh.org)

II. SOS AS A MODEL THAT ADDRESSES PROBLEMS OF EDUCATION AT THE INTERSECTION OF THREE DOMAINS

In the evaluations we conduct at Inverness Research Associates we have the occasion to study many different investments in educational reform, some situated in the domain of informal education institutions and others involving the formal education system. From our external perspective, we see the SOS project as an important attempt both to work within and to bring together three distinct domains, each with its own institutions, practitioners, and research base.

Figure 2.
The domains within which the SOS project is working



Below, we examine the three domains in more detail. We identify challenges that are particular to that domain, and highlight progress the project has made thus far in addressing them.

Domain 1. The professional development of science teachers: helping teachers learn science

Teacher quality is a pressing national concern. In the last decade research, blue ribbon commissions, and major federal legislation have all pointed to the need for improved instruction and learning outcomes, and particularly in math and science. (National Center on Teaching and America's Future's *What Matter's Most: Teaching for America's Future* (1996); *No Child Left Behind* legislation (2002)). Within science education, a critical challenge to teacher quality is the lack of content preparation and background that many teachers bring to their science teaching (NRC's *Science Education Standards* (1996)). To date it has been very difficult for professional development programs to offer teachers a high quality opportunity to gain that kind of knowledge. Many science teachers have not learned science as "real science" – i.e., as an inquiry-based discipline generating knowledge in certain ways—but rather have learned science "second-hand" as an already formed and distilled body of knowledge. As teachers, they too often receive professional development from developers who themselves may lack the scientific background required to design high quality courses for teachers. Similarly, scientists who attempt to teach teachers often do not understand the particular pedagogical content needs[4] that teachers have. And even when professional developers and scientists have the necessary expertise to engage teachers in "real science," pressures to make professional development "relevant" mean that courses are often designed so the science is heavily mediated by accountability concerns and pressing concerns for finding classroom applications. In short, there are many reasons that teachers often lack a first-hand understanding of the discipline, but whatever the reason, teachers lacking this experience are not likely to be able to teach science authentically to their own students.

This project aims to address that challenge directly both in teachers' inservice professional development and also in teacher preparation. The challenge is to help teachers have the opportunity to gain a first-hand and working knowledge of science—a knowledge of science that arises from accurate understandings of, and real experiences with, scientists and scientific research.

[4] Shulman describes this kind of working knowledge for teachers as "pedagogical content knowledge" — a knowledge of the subject matter that empowers teachers to explain, illustrate, and demonstrate key principles and ideas.

Key outcomes to date in this domain

The SOS courses provide teachers with first-hand, authentic, learning experiences. Our studies of the learners' experiences convince us that the courses developed by the SOS project are, in fact, effective at providing teachers with the opportunity to learn science in a more authentic way. This project offers strong affirmation about the power of first-hand learning for teachers. Some examples and evaluation findings follow:

- In How to Think about Life in the Universe, course participants study the Drake Equation, through which they calculate the likelihood of our encountering extraterrestrial life by making a series of estimations informed by what they learn in the course. Participants in the Spiders course investigate spiders in their own locales using techniques they learn from videos of the course scientist at work. In the Earth course people study a local geological feature so they can share knowledge about the earth, each drawing upon what they have learned locally.

- Both participants and scientists valued these kinds of learning opportunities; both saw them as rare chance for the non-scientist to engage in scientific research and inquiry. A scientist with the fishes course imagines learners in their kitchens, looking – really looking – at a fish:

> For me, a great step is to know that after the course, the student takes with him a sense of how diverse fishes are and what it "means to study fishes" (which involves getting familiar with the research activity per se). Just to imagine the student in front of a fish from the fish market, trying to observe and describe it, and in the process getting aware of features that he shouldn't have paid attention before, is already an accomplished assignment. That's my goal, to make him sit and observe and then compare. He won't learn much about the 'world of fishes', but he will certainly be putting in practice what scientists do for their research.

- Most participants who completed end-of-year surveys (76%) say that the courses gave them deeper insight into the work of scientists. A teacher we interviewed mid-course shared an example of this kind of experience she would be having that very night:

> Well - at the moment the most engaging [experience] is the stargazing. I have gotten my family involved. We dug out the old telescope and are headed to the airport outside of town tonight to carry out this assignment.

We believe that the SOS courses demonstrate that scientifically rigorous courses can be made to be both engaging and accessible for teachers. Teachers are drawn to the courses by the specific topics and questions they consider. The science that teachers encounter in the courses is rigorous and "true" to the discipline; the science is also uniquely engaging and accessible to most of the teacher participants. The content is not packaged or translated "for teachers." This suggests that teachers, as an audience, have capacity to be interested in, succeed in, and gain from rigorous science courses. This is not to say that these are PhD. or graduate courses, and they have limits because of the 6-week format, but they give teachers access to significant scientific content. A teacher who has taken several courses (and is also pursuing a Master's elsewhere) summarized the various aspects that appeal to teachers:

> The inquiries were very thought provoking, the feedback was very supportive, and there were no right or wrong answers. The courses were very challenging. They have all kinds of resources above and beyond the typical or conventional courses, and all the information is so timely. They were not preaching the same old material that you often get from textbooks in uninspiring college classes.

AMNH scientists who are conducting current research in the field create and co-lead the courses, bringing world-class expertise to the enterprise.

- For example, Dr. Mark Norell, the authoring scientist of the Dinosaurs course, has along with AMNH provost Mike Novacek, made some of the most important paleontological discoveries of the decade. His work is featured in popular media (including cover stories in the New York Times, Time and Newsweek, as well as coverage by the Discovery Channel, etc.) as well as major scientific journals. As another example, the authoring scientist for The Study of Spiders, Dr. Vladimir Ovtsharenko, is not only a research scientist in the Division of Invertebrate Zoology at the AMNH, but also a Curator of the Arachnological Collections at the Zoological Institute of the Russian Academy of Sciences. He has collected spiders on 5 continents, written 40 scholarly and popular articles, and has taught in Russia as well as New York.

- The overwhelming majority of participants who completed our mid-course survey (83%) say that they took the course(s) for personal interest. Nine in 10 (91%) of the teachers responding to our end-of-year surveys believe that the courses have contributed substantially to their personal background knowledge; 74% report that it rekindled their passion for science and the work of science.

- Teachers appreciate the unique contributions such researchers can make:

> These classes are unique because of the very knowledgeable guides and experts from the field. They were people who have traveled around the world. It was great seeing the specimens they work with. The guides and scientists were impeccably informed and very professional.
>
> I especially liked the cutting-edge quality of the research – the kinds of questions, the kinds of tools available to scientists, and the ways in which scientists use available information to make inferences.

- An Inverness researcher who has both taught high school science and directed professional development at the Tech Museum of Innovation notes that:

> The topics were presented in a compelling, user-friendly manner. The kinds of questions and issues discussed were inherently interesting to most of [the course takers], regardless of our science interest or background. How do we know what's in our genes? Would YOU want to know if you are predisposed to a genetic disease? What are the ethical implications of knowing the human genetic map?

While the courses do not focus on pedagogy per se, evidence suggests that they not only add to teachers' science content knowledge, but also provide teachers with resources and activities they can use for their teaching. This suggests that courses focused on authentic science (as opposed to pedagogy *per se*) are relevant and useful to classroom practitioners. One reason the courses are useful is that the resources provided by the courses are so rich that they create access not only for teachers but also for students. Moreover, the best assignments for course participants model good assignments for students. It is not that the courses do not talk about pedagogy; they are just not <u>about</u> it. (We discuss this at greater length in Section IV.)

- Three-quarters of the teachers who answered our end-of-year survey report that the courses provided them with hands-on, inquiry learning experiences that can serve as a good model for their work with students (73%), that it provided resources they can share with their students (72%), and that they have already used what they learned as background to create a unit or lesson for their students (71%). Teachers commented:

> [What was valuable to me was] rich content which I can use as I teach students, along with valuable resources and current information.
>
> Though they weren't registered, my students took the course with me.

The independent assessment of the SOS that we commissioned for this report builds upon these points and makes several suggestions for future refinement of these or similar courses.

> The six-week long course includes many activities that, collectively, could take more than 40 hours to complete, especially if more formal learner accountability of the assignments is taken into consideration. Given this short time frame, teachers may need additional time to gain teaching strategies and in-depth understanding of science content needed for reform-based teacher professional development (TPD).
>
> While the course [Earth: Inside and Out] was developed in the context of an informal science learning center and appears to address standards-based education, the addition of a document that links the course to national science standards would be useful to make them more apparent to learners.

Reflections on outcomes to date in this domain

There are different theories and models of how best to give teachers better content preparation. Current professional development models often intertwine content and pedagogy. In the past, professional development courses for teachers mirrored the traditional university model: no pedagogy, but also little if any inquiry or engagement with compelling scientific research questions. This experiment suggests that when teachers do have an opportunity to engage with science content in an inquiring way, when they learn science content in the context of authentic scientific research, then science learning is interesting to them, they learn content that is valuable, and it gives them perspective and knowledge they can apply to their teaching.

Also, it is important to remember that there were a number of ways this experiment could have failed. It could have offered rigorous courses that teachers were not interested in or found “too hard.” (In fact, many participants in the first round of courses found them overly rigorous and inaccessible. But because AMNH was consciously prototyping, they redesigned the courses so they were rigorous but still accessible to teachers.) Or it could have offered courses that taught a particular topic, but teachers would not have learned enough to be helpful in their teaching of the topic. Or the online platform might have made content learning too complex or too difficult. Through careful testing and refinement the AMNH staff has skillfully steered the design of the courses away from these very real pitfalls.

Domain 2. The role of science-rich institutions: supporting educational reform in schools

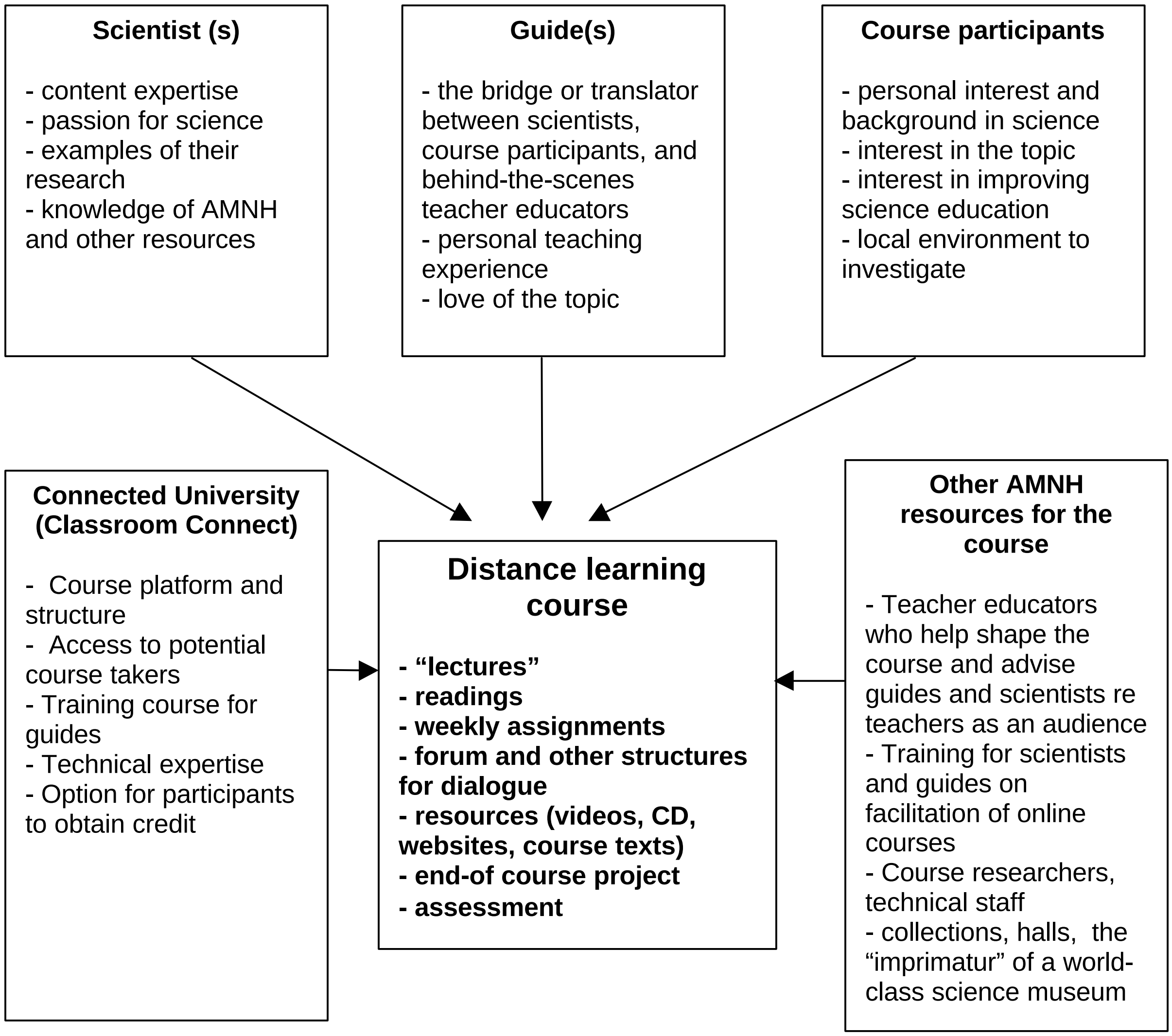
Science-rich institutions have the important role of housing and promoting scientific knowledge (and in the case of AMNH, sponsoring original scientific research) for the purpose of general public education and cultural benefit. Science museums, aquaria and zoos have become very popular with the public and very successful at developing exhibits and programs that serve them. The challenge many of these institutions now face is to find ways to use their resources and expertise to help improve the quality of science education within the schools. Many science museums are positioning themselves to help shape science education (Bloom & Mintz, 1992; Durant, 1992, 1996; Miller, 1991), including teacher education (Middlebrooks, 1998; Institute of Museum Services, 1996). For example, in a national survey of museums and science centers that Inverness Research conducted in 1996, we found that informal institutions provide nearly half of in-depth professional development in science (35 hours or more) for elementary school teachers. Science-rich institutions and schools exist in different institutional, regulatory, and political contexts—and, as such, their cultures and goals often differ significantly.

This project represents a sophisticated effort to find effective and efficient ways to bring the expertise and resources of one of the country's preeminent science museums to bear on the problems of science education in the schools. The model being developed in the SOS project might well be generalizable to many other museums and science rich institutions which similarly seek to support science teaching in the school setting.

The figure on the following page summarizes the model, showing the contributions of the AMNH and CU[5].

[5] For this phase Inverness Research has also contributed feedback based on formative evaluation of the courses. We discuss the CU relationship in the discussion of "Domain 3" below.

Figure 3.
The SOS course model



Key outcomes to date in this domain

The SOS project has created course designs and structures, as well as educational resources of multiple kinds that indeed make it possible to bring the human, intellectual and material assets of the AMNH to teachers across the country in appropriate ways.

The museum has created courses that are built around two of its fundamental and distinctive assets. Some of the courses (Spiders, Fishes, Sharks and Rays, Mammoths, Dinosaurs) have at their core AMNH scientists and cases of their work; others build and extend upon the museum's curated exhibits (Earth, How to Think about Life in the Universe, and Genetics). Course designs and structures make it possible to bring both the human and material assets of the AMNH to teachers across the country in appropriate ways.

Both types of courses – those built around cases of science scientific investigation and those that build upon exhibits -- are rich and distinctive in ways that appeal to teachers. They both seem like viable ways to think about how to build a course around an institution and its key assets. This is germane to a variety of ISIs. While the resources of the AMNH are vast, the courses draw on specific areas of strength, not on the AMNH as a whole. Although many ISIs lack the overall capacity and resources of the AMNH, they might still be able to offer similar courses based on the institutional assets can bring to the courses.

By training and providing teaching experience to the diverse and numerous course leaders (scientists and guides), this program is building its capacity for providing professional development. These lead teachers, museum educators, and scientists are in most cases getting their first online teaching experience, and all are learning to teach better – online or elsewhere. And because they receive careful training, they teach in closely coordinated teams, and they teach in a very visible and public format, they form a group that shares goals and norms in a way that individual teachers with more autonomy certainly would not. As a group, they convey the AMNH stance toward the teaching and learning of science quite consistently.

The ongoing and intensive participation by AMNH scientists—post-doctoral researchers and senior curators alike—demonstrates the commitment to teaching that is present in many scientists working in science-rich institutions. In fact, the AMNH is developing a strong "faculty" of what might be called "scientist-educators", and this project has led to a mutually beneficial interaction between them and teachers across the country. You might expect that because this is not a university, ISI-based scientists do not want to teach, but in fact they enjoy teaching and report many rewards. If these scientists are any indicator, other scientists might well enjoy the rewards of teaching their passion and sharing their own work and knowledge.

- On the SOS website for the courses, a Sharks and Rays course scientist reports that he sees the SOS courses as a way to communicate his enthusiasm and knowledge about fishes to others:

> It's about more people having a better understanding of the subject and how it affects their day-to-day life in ways they'd never thought about.

- An authoring scientist for the Fishes course elaborates:

> I am truly interested in the "overall goals" of the project, and all the issues around the role of scientists in formal and informal education. I am very aware of that, so, for me it's not enough 'just to talk about fishes'. . . . I've been always interested in the way science reaches the public (for instance, at some point I thought of taking courses on scientific journalism), but the truth ism, this has been the first time I've had the opportunity to do something like this. Most scientists are not directly prepared to take part of experiences like this (on the contrary, we receive overtraining on how to present ideas the more complicated you can!!). It's also true that, working at a museum makes you more psychologically open to this outreach experiences.

One reason leading the courses is worth the effort to scientists is because it taps their strengths and doesn't overburden them. The AMNH has developed a course development process that gives them authority over the content and design of courses, and takes away the drudgery; in a university they would be responsible for all aspects of the course.

- An authoring scientist for the Earth course best voiced this perspective:

> Staff provided some guidance on the nature of course materials. This is quite important, since they are the ones with the experience in this. The staff made very good videos, but they made the videos that we wanted to be made. They also helped find web-based resources, assembled materials, obtained rights to articles, etc. etc, and all this was very helpful and made the course development go smoothly. That said, I would not want to be involved in a course where someone else made decisions about content or how to present the content.

- An authoring scientist for the Fishes course concurred:

> I'm totally satisfied with both the process of developing the course and working with the NCSLET staff: I really enjoyed the experience [and the challenge] of developing the material around the kind of research we do, making it available in a different (new for me) learning context. In preparing the draft I did rely a lot on the feedback received daily from the content specialists and educators working in NCSLET. Of course, also important was the interaction with the staff that is more media-oriented, particularly in relation to what we really do - or how we can do it easier - in terms of the Web Pages.

These institutions are repositories of expertise, and there are different ways to bring the assets of non-authoring scientists into these courses. Non-authoring scientists can teach a course authored by a colleague, they can contribute a "case" of their own research for study to an existing course, or they can be a resource in more prescribed ways. Moreover, the authoring scientists see the value of passing along the leadership; in both cases to date, they know and approve of the qualifications and attitudes of their replacements.

- The authoring scientist of How to Think about Life in the Universe has moved to a university position. When we asked how he felt about passing on leadership of his course, he responded:

  > I'm very happy to have someone else take the course on. This is for two reasons. First, I think this subject can really benefit from the input of another scientist. Since it treats what is an open scientific question, there are always new discoveries to consider as well as new ways of thinking. . . . I know that [the new course leader] is very excited about this subject and knows much more than I about certain domains of the science. I'm also confident that her passion and enthusiasm for teaching will really be great for the students.

  His replacement, another scientist in AMNH's Astrophysics Department, acknowledges that her knowledge base differs somewhat from the authoring scientist's, but sees value in her new perspective.

  > I cannot claim to be an expert in, say, hydrothermal vents or the make up of DNA. However I am an expert in the planetary searches and methods, how to make a planet, and the astro-related part of the course, in general. I also have been exposed to some of the typical debates (like the rare earth debate) and have general opinions . . . . If I had written the course I would already have put my thoughts in the essays, and would have brought nothing new to the table while teaching it. I think it is a good idea to have the author of the course be different from the teacher of it.

  And the course guide, who had been with the course ever since its developmental phase, noted that the transition had not been entirely smooth for him, but ultimately it was a positive change.

  > [The new scientist] brought new perspectives and expertise to the course, which added to the learners' experience. In the end, this was a positive development. I am an old dog and I resisted new tricks for a week or two. Such is my learning curve.

People who work in different units within the institution, and who have different interests and status, can collaborate successfully when they work

together on challenges that are interesting, worthwhile and real to them personally, and where the assets brought by individuals complement one another. As an institution of considerable size and complexity, the AMNH houses specialists with varying backgrounds and interests and who generally work in separate arenas. In quasi-academic institutions like this, internecine conflicts are often part of the institutional culture. However, contrary to the assumptions that scientists, educators, and exhibits people have a hard time working together, this project has created a model of how well they can work together. It is a feasibility proof. The SOS program required in-depth collaboration among those who work in research, collections, exhibits, education, and production. Their experience holds lessons related to the principles and practices that make such intra-institutional collaborations workable.

- There is a perceived mutual benefit to working together. The process has been organized so that people are able to offer their particular expertise in a way that contributes to the whole and complements the contributions of their colleagues. A scientist appreciated the pedagogical expertise of guides because:

  > I think having someone like the instructors in the course I did who can actually tell me what to do [e.g., suggesting when to interject content information or an example from personal research experience; clarification; or a question] is a great help.

  And a guide valued the behind the scenes support he received from NSCLET staff:

  > Without [the teacher educator who was a troubleshooter and support person for the course], I know that I would be less effective, because I would be consumed by details.

Course developers adhere to traditional institutional norms that allow people to maintain their status, while adjusting to working together. Scientists are afforded considerable respect and authority. In the early courses, sometimes education or production staff made changes to the science, and it angered scientists, so staff learned always to consult with the authoring scientist. On the other hand, the scientists have adapted to the model of a 6-week course, and have ceded to education staff the task of finding resources. These adjustments did not work for everyone, but it is a model people can learn from.

The courses created new professional roles for some staff and educator friends of the museum. There was no obvious repository within the institution of one kind of expertise needed for the courses—online facilitation skills needed by guides. However, at the AMNH as at most other ISIs the vast majority of staff members have a deep enthusiasm for science, and many also bring some level of content knowledge and instructional experience as well. Moreover, because of its history and other educational initiatives, the museum was able to hand-pick a few local educators to guide as well. The SOS had considerable success finding suitable candidates for guide training from these two pools.

The content and focus of the courses is not governed and constrained by the demands and customs of the formal education system. The result is that SOS courses have potential for a richness and authenticity that teachers can immediately recognize. The SOS courses are privately funded, and they are anchored in the real work of the AMNH, a knowledge-making institution that is doing science. Hence they have been developed to draw upon the distinctive institutional resources and to respond in a broadly conceived way to needs in the field, <u>not</u> simply to address the crisis or content standard of the week as put forth by some agency's Request for Proposal.

The genesis of these courses is critical. The courses arise out of the real interests, knowledge and work of the research scientists; at the same time there is enough connection to standards that teachers around the nation are seeing the connections. The courses can be used to enrich a standards-based curriculum, but, importantly, the standards policies are not driving the courses.

- A scientist eloquently spoke to the need for the course in his specialty, and his belief about its potential to make a significant and important contribution to the scientific literacy of teachers, and in turn, their students:

> Speaking from my perspective as a scientist I would like it if everyone had a much higher degree of scientific literacy but I also understand that it is unrealistic to expect everyone to be as interested in biology as I am. Still there is a question I always like to ask biology teachers. It is 'In your opinion, what does a person need to know about Biology in order to function as a well informed citizen in the 21st century?' The answers that I usually get have a lot to do with national and state standards and how these are arrived at. While standards are an answer to this question I think it is much more realistic to ask people what they think of stem cell research, or cloning, or gene therapy, or forensic DNA evidence, or GM foods etc. The sequencing of the Human Genome is in my opinion the most important event in human history. Our view of the world and ourselves has changed forever and the implications of this information will lead to drastic changes in the way we live. I think that it may be possible to get by with only a vague understanding of zoology, botany, anatomy and physiology etc. But an understanding of what the genome is, what it does and how it does it will have an affect on everyone's life at some point. In order to make well-informed choices the general public needs

> information so that they can separate science fiction from fact. I think that a course like this is an excellent step towards demystifying the science and making it more accessible and usable for the members of the general public.

Reflections on outcomes to date in this domain

Our evaluation to date suggests that there really can be a bridge between an informal science institution and a nation-wide market of teachers seeking content preparation. This phase of the SOS project is, we believe, a kind of a feasibility proof of a solution to the problems outlined in this domain.

Domain 3. On-line learning: creating professional learning communities

Information technologies (specifically, web-based educational platforms) have the potential to extend the AMNH's reach not only "beyond the walls" but beyond New York and to the entire nation. The promise of high quality professional development over the internet is great, but there are both educational and technological barriers to overcome. The AMNH is not in the business of building and maintaining technical platforms for on-line learning, nor has it been in the business of teaching at a distance.

Key outcomes to date in this domain

The AMNH has learned lessons in this area that prospective course developers are advised to heed.

Prototyping is essential in this arena, and substantial revisions and adjustments may be necessary to remedy problems that surface in the prototyping. Course takers during the first round of courses had many problems with the technology and with the interface between the user and course. SOS responded and in recent course offerings there have been virtually no comments from scientists, guides or participants about technology presenting a barrier.

- **The pedagogy of on-line teaching has both similarities to and differences from the pedagogy of in-person teaching, and more specifically the pedagogy of teachers' professional development.** Through each successive round of courses, the project learned a great deal about the design of assignments and activities, and about course facilitation, communication, and interaction over the internet. They have shown that it is possible to create distance learning experiences that are not "correspondence" courses, but that in fact offer rich content and well-designed interactive learning experiences.[6]

There are trade-offs in deciding between building your own technical platform for on-line learning or relying on another platform. Early in the project, SOS development staff considered mounting its own platform, and decided against it. They then invested considerable effort in identifying a partner company, Connected University, which had an existing technical platform with potential to operate AMNH courses. By utilizing CU, the SOS project has made real progress in developing a workable platform for professional development of teachers—without having to invest in building their own.

- In retrospect, some outcomes from this decision seem to have been for the best: Course designers didn't stretch themselves too far, so they could concentrate on their core competencies. For example, using an established online platform is a practical, relatively easy way to provide credit; your own institution does not have to change to do this. More generally, distance learning is a fast-developing field, so a platform developed even several years ago might have soon become outmoded or expensive to update repeatedly.

- There have also been challenges: Course designers had to adjust to the CU platform. For example, they wouldn't necessarily have organized courses the way they did had the CU platform not constrained them. The guide training offered and required by CU was not sufficient to prepare guides for SOS courses, and had to be substantially augmented by SOS. The visibility of their courses is dependent in large part on CU's market penetration and ability to attract the kind of learners who might be attracted by SOS.

- Moreover, CU brings an audience with it, but it is a different audience than one might find through the science professional associations. And a recent change of ownership has shifted the platform's focus away from science. It is clear that they probably made the right decision based on their options four years ago, but it is not clear that they would pick the same platform now. At the same time, the courses are now shaped to fit

[6] Our independent reviewer suggested the courses would be even richer if learners were given more structured opportunities for collaboration and peer feedback.

CU and they work well; their investment in CU-compatible courses is substantial. This is an open question. To choose a partner means gaining an asset one does not have, but it can also bring about constraints. Course designers made the best decision they could at the time, and they made it thoughtfully, but it could yet turn out to be a significant issue as the project moves to a beta-testing phase.

In her assessment of the CU platform, our independent reviewer concurred that CU was a reasonable platform choice for the courses:

- The CU Platform provides a way to leverage rapid online course development. The CU user interface and navigation system provide both beneficial features and some challenging elements compared to other learning managements systems such as Blackboard or Lotus Learning Space.

Scientists like teaching online. They find the teaching itself rewarding, and also are happy to develop new teaching repertoires that they say are already proving useful in other venues.

- A scientist who has led four sessions of his course sees:

  > … lots of rewards [to teaching online], especially seeing the participants 'get it' by simply communicating in writing with them. This experience also helps me a lot with my writing for the general public, in that explaining things to the people in this course makes it all that easier to converse with the general public.

  We asked scientists if they find the format constraining, and he countered that:

  > I don't think there are any constraints here at all. In fact I think the format is rather liberating with respect to the old fashioned 'face to face' interactions."

- Another scientist who has moved on from the AMNH expects to be able to use the experience in the future:

  > It's been a great experience for me. I learned a lot about how these types of courses work and what it's like to teach this way. Practically speaking, this experience will translate over to courses like this I might wind up teaching or overseeing [where I teach currently].

- That is not to say that scientists have no reservations about the format. It is just that in general, they thought that the advantages of online learning outweighed its disadvantages: One scientist reflected on his recent first experience teaching online:

> The drawback to this type of teaching is that the interaction is always delayed and there is no immediate opportunity to determine if your explanations are satisfactory. It is also frustrating to not be able to interact in a give-and-take as one can in a more traditional classroom setting. I found that to be a rather large inconvenience, but the ability to reach a much larger audience through remote learning far outweighs the disadvantages.

Careful development, documentation and sharing of the "technology of online teaching" among course leadership make it possible to mount courses where the course leaders, as well as the course takers, participate at a distance. This finding means that participants can benefit from the input of scientists actively engaged in field research, as well as from the guidance of hand-picked science teacher-guides from around the U.S.

- A guide in the Genetics course teaches in Cuyahoga Falls, Ohio. A teacher since 1967, he first got involved in genomics and genethics in 1992 when he was given a SciMat fellowship to study and develop teaching units in that area. He was guiding another course for CU several years ago, when he applied to guide for SOS. He took the Genetics course before training to guide it. He describes the rewards of guiding for the AMNH:

> I feel a real sense of accomplishment helping other teachers update and expand their understanding of the course topics and helping them design lessons that will impact so many students all across the country. The topics of the courses are so relevant to science teaching today, as are the course structures and goals.

Leadership at a distance is one of the newer features of the SOS courses, and needs additional testing and refinement. It does seem to have potential because scientists and guides are sufficiently interested in leading the courses to be willing to lead even when they are engaged in other work elsewhere, and because AMNH course managers study and document each aspect of the courses to refine their preparation of scientists and guides leading courses that come after.

- One course scientist, for example, conducted his online course duties from Scandinavia

<u>Reflections on outcomes to date in this domain</u>

Course producers working in the online environment can expect that this environment will continue to shift beneath them for the foreseeable future. The technology is evolving, and the first wave of online courses for science teachers that focus on creating a learning community is still breaking. Those who are at the front of the wave don't know for certain the best way to go because there is not enough precedent. At this point, we do know that it would have certainly taken a lot more money and institutional changes for AMNH to create and publicize its own platform than it did to piggyback on the Connected University platform, that the CU platform enables the SOS courses to include most key features commonly available in distance learning courses for teachers, and that it is functioning adequately from the point of view of course leaders and learners. There is simply no way to know whether a platform custom-created by the museum would have been that much better than CU's.

Summary: An emerging model and its distinctive characteristics

The Seminars on Science project is working within, and making contributions to, each of the three domains described above. But perhaps more importantly, we believe that it is in the *intersections* of these three domains that the project may make its greatest contribution. While the eight courses all vary, they do share underlying assumptions and design principles as they seek to integrate the scientific expertise and resources of the museum, the professional development and production expertise of the Education department, and the on-line designs of both the Center and Connected University. The courses thus illustrate and inform a distinct approach that we regard as an emerging model and the lessons learned within each of these domains will be important to people in a number of fields who are working to serve teachers.

Like all models, the SOS course model is defined by its key features and design principles. For example, the model emphasizes the appropriate involvement of practicing scientists, who are able to bring examples of their research and their passion for it to teachers. Also, the model includes well-trained guides who play the primary role in leading the courses, are the key contacts for learners, and who help everyone involved communicate and interact in the new on-line course environment. And behind the scenes, teacher educators help shape the courses and advise the course leaders on matters pertaining to teachers as an audience with particular characteristics and needs. This configuration of course leadership is unlike that of other AMNH educational efforts, unlike Connected University's system for using guides, unlike a traditional university professor and TA. It is one example of a new and distinctive design feature engineered at the intersection of all three domains. Additionally, the model includes on-line structures that promote access to a rich array of resources, and, perhaps more importantly, it creates an on-line "learning community" where teachers, scientists and guides can all raise questions and have discussions centered around the real science they are studying. Again, this feature is a distinctive adaptation that was created where the domains overlap.

The following comments of the independent reviewer suggest that others may regard the SOS model as a significant contribution to the field:

> Overall, the SOS course makes a contribution to the field as an example of a design that takes advantage of museum resources, existing exhibit assets, online learning opportunities, and involvement of learners, museum scientists, and staff.
>
> The online course provides a 'package' of rich science content, basic activities, resources, documents and online course features. The course is very accessible to new online learners and positioned well to be successful as a professional development opportunity for science teachers.
>
> There is a strong foundation of museum-created content, compelling science illustrations, and science explanations in digital video format.
>
> The Museum has taken on a new role in informal science education in the development in online courses for formal education. Despite this new experience, the Museum appears to have adopted several of the best practices in the development of new online course materials.
>
> The course's strength is its science content drawn from unique assets and resources from the Museum. One can envision this course being used to supplement both on-the-ground teacher professional development as well as a teacher's classroom-based instruction.

Before moving on to discuss the impact of the courses to date, we need to emphasize that like developers of any new model, AMNH staff have encountered some challenges that may prove difficult to overcome, given the characteristics of their model and the educational landscape they are working within. These may be, in fact, so intrinsic to this type of course that they should be regarded as its probable downsides, not just risks associated with it. One important factor to consider is that development costs are considerably higher than for a conventional course. In fact, it might be more accurate to liken the development of these courses to writing textbooks, because course development and production are time intensive and require considerable coordination and management, especially if you are rolling out a series of courses under tight deadlines as AMNH did. And while the courses are in session, it can take considerable time per student to lead the class. For example, we saw extended periods in some courses when course leaders struggled to re-ignite faltering course participation, and even when courses were running smoothly, the shared leadership meant that there were frequent consultations on sustaining dialogue and responding to particular participant questions or coursework. Another issue is that because the courses are grounded in the real experience of scientists, offering a new course entails recruiting, preparing, and supporting one or several new scientists to lead it. And scientists tend to move on to new work, so one should expect to need to find and train non-authoring scientists to assume leadership of courses. Similarly, there is a need for a system for ongoing support and recruitment of guides.

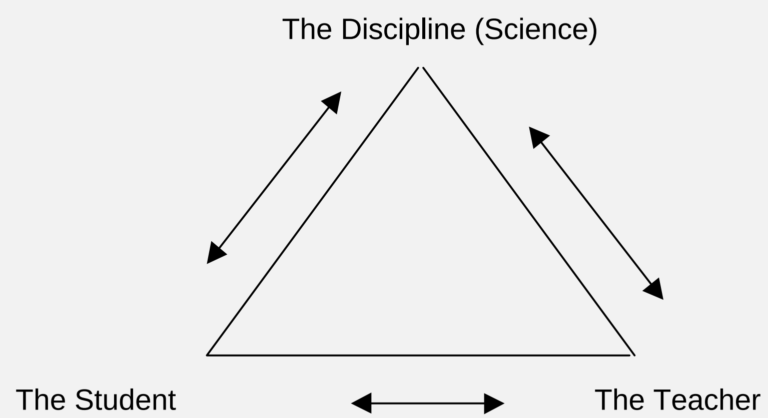
Hence it is important to keep in mind that the very success to date of the courses creates the awareness of the next challenges to be addressed, and these challenges generate the next questions for design. We consider next steps for the project later in this report, in Section V.

III. CONTRIBUTIONS OF THE SOS COURSES TO TEACHER KNOWLEDGE AND CLASSROOM PRACTICE

The relationship triangle: Teacher, Student, Discipline

As we study innovations in teaching and learning, we often use what we call "the relationship triangle" to describe the dimensions along which teaching and learning occur and can improve**.** Consider that the teacher, the student, and the discipline (in this case science) are the three pivotal elements of the learning process. Then, place one of each of these elements at the corners of a triangle to represent a vision for high-quality instruction.

Figure 4.
The relationship triangle for high-quality instruction



Note that this triangle is about relationships[7]. In the case of teaching and learning, the triangle points to the powerful dynamic that is set in motion when a teacher and student engage with each other around a shared interest in the learning of a discipline.

Note that the line connecting the teacher and the discipline is a double-headed arrow, suggesting that a strong teacher has a meaningful and long-term

[7] This triangle derives from Martin Buber's I-Thou-It paradigm, which suggests that this powerful dynamic takes place when there is a three-part relationship between I, Thou, and some "It."

relationship with the discipline. This is the teacher who is really interested in science, has a moderate to strong background in science, reads about it in the newspaper, watches NOVA, goes to museums, and genuinely enjoys learning more and more about science. Such a teacher certainly knows a lot of science content, but beyond that, he or she truly has a long-term multi-faceted relationship with the discipline.

Similarly, the line connecting the teacher and the student also is a double-headed arrow, suggesting that a strong teacher has a meaningful relationship with his/her individual students, built on authentic interest in them as individuals, and a genuine commitment to helping them learn. In a science classroom, teachers need to know what interests of their students, how their students think about the discipline, and how they can be engaged and motivated.

High quality teaching and learning experiences in science – or any other discipline – create a third double-headed arrow between the student and the discipline. That is, it is the goal and authentic intention of a strong teacher is to help develop the relationship between student and discipline. The teacher not only wants the student to learn the basic content knowledge, but, far more, wants the student to become excited by, interested in, and skilled at future learning in the discipline.

Where there is no relationship triangle in place it can be because the teacher does not truly understand the conceptual underpinnings of the discipline (a common situation for elementary science teachers). Or it can be that a teacher may not be able to interest many students in the discipline because he/she cannot help them connect with what it is that the teacher loves about the discipline. In a dynamic classroom the teacher has a rich repertoire of strategies and approaches for helping make the connection between students and discipline.

Contributions of the SOS courses to the relationship triangle

Using the relationship triangle as a way to think about the impact of the SOS experiment on teachers who have taken courses to date, we examine below the evidence that suggests to what extent and in what ways the courses strengthen each leg of the triangle.

But first, we want to describe briefly the course takers, because in order for these courses to be effective, the AMNH has to understand the learners they are attracting and match the courses to them. These learners represent a certain segment of the teaching force.[8] Moreover, unless teachers have a fairly positive experience taking the courses, they are unlikely to persist in them and benefit from them fully.

Learner characteristics

The typical course participant is an established veteran teacher with an interest in science and with the initiative to seek out personal learning opportunities. A year ago (in August 2001) we conducted a study of learner characteristics of the 132 SOS participants who had provided (at their option) background information to CU up to that time. There is no reason to believe that the participant profile has changed very much since then, except that they probably represent more states now.

- The majority of people that the courses attract are teachers of science (70%), though general educators (30%) and computer educators (19%) are also well represented.
- Most enrollees work at the middle or high school level (65%), though 35% are at the elementary level. Many people have multiple responsibilities and roles, so they may also apply what they learn in the courses to work as technology coordinators, administrators, and college faculty.
- They represented a total of 29 states (again, this figure would presumably be higher now). While 25 states had 1 – 6 participants, there were up to 22 participants from a handful of states for reasons that we do not understand (New York, Texas, California, and New Hampshire.)
- 77% had taken one SOS course, most of the rest (14%) had enrolled in two courses, and a few (7%) had enrolled in three or more courses.

We learned more about participants from our mid-course and end-of-year surveys.[9] It appears that our survey takers are demographically similar to the course takers who filled out CU's profile sheets.

[8] Outcomes for teachers with different characteristics may be different; in the next phase of course development the SOS staff is likely to reach a broader spectrum of teachers.

[9] Two-year summaries for both surveys are included as Appendix C of this report. We received 84 mid-course surveys (including a few from people who submitted them for more than one course),, as well as end-of-year surveys from 74 individuals. An unknown number of course takers completed both types of surveys, and others completed just one.

- Most (78%) are K-12 teachers (though they may have additional professional roles as well).

- Of these teachers, nearly half (45%) teach high school, a third teach middle school (33%) and the rest (21%) are elementary teachers.

- They are, on the whole, experienced teachers. Over half of them (55%) have taught science for over ten years, and another quarter (27%) have been teaching 4-10 years.

- Course takers bring some science background to the courses. Most course participants (75%) have either some college course work (40%) or a BA in science (35%). About 2/3 (63%) have some background in the topics covered. Most of the rest (30%) are interested but bring little background, and a handful (7%) have a great deal of background.

- The overwhelming majority say that they took the course(s) for personal interest (83%). About half as many indicate that they were taking them for professional benefits (37%) and/or immediate usefulness for the courses they were teaching (33%). Course credit is <u>not</u> the major draw for these teachers: 40% received credit for the course. Most of the others (68%) say that they could get credit if they wanted it.

- They have limited experience with online learning; for at least 5 in 10 (54%), this is their first distance learning experience. 2 in 10 (17%) had taken another AMNH course prior to completing our survey; 3 in 10 had taken one or more other CU courses (33%) and/or distance-learning course from another provider (29%).

- While we have no conclusive evidence that teacher participants tend to be exceptionally able or committed to teaching, those involved with offering the courses, and our own interviewers of course participants, perceived the participants to be a high-functioning group. As a scientist observed:

> I think the learners are more qualified than most teachers, simply because teachers who are less enthusiastic simply would not do this unless somehow mandatory.

We hypothesize, then, that these courses provide resources and opportunity to learn for teachers who are motivated, personally interested in science, perhaps isolated, and willing to use personal initiative to learn for themselves

The course-taking experience

In the first offering, the technical interface was an obstacle and the courses tended to be burdensome in terms of their demands on teachers. However, with each successive iteration, the courses have improved on both counts, and now the course-taking experience is a positive one for learners.

Over the last several years CU has revamped its interface and AMNH has refined instructions and procedures for learners as they begin courses; participant ratings related to getting started have improved since the changes were made.

- Only a small minority (14%) have had to learn anything new about computers or CU to take the courses.

- Most people (60%) with prior experience taking an online course told us that the experience getting started in the SOS course was similar to starting other courses. Again the rest divided among those who said it was harder (18%) and easier (22%).

- This year only a few participants who completed the mid-course survey (8%) said that getting started in the courses was harder than starting other online courses; last year, 29% said getting started was harder. In particular, they find figuring out the website and using the forum easier now. A year ago half of the course takers (47%) said it was very easy to figure out the website; by the end of this year, over two-thirds (67%) said they had no problems figuring it out. Similarly, this year's participants found it easier to figure out how to use the forum (82% said it was very easy, up from 62%) and 69% found it very easy to figure out what to download (up from 42%). The only aspect of getting started is that continues to pose a barrier for a significant minority of course takers is getting books (24% found it at least somewhat difficult this year).

Courses require a substantial, but not overly burdensome, commitment of time by busy educators.

- The typical participant (i.e., 44% of people responding to our mid-course survey) needed to spend between 4 and 6 hours on the course the first week. The rest divided pretty evenly between those who spent less time (27%) and those who spent more (29%, including 10% who spent over 10 hours).

- At mid-course, participants continued to spend 4-6 hours a week on average (45% spend this much time), with 24% spending less time and 31% spending more (just 7% spend more than 10 hours a week). They find the course load just right (58%) or somewhat heavy (38%). Just a handful of course-takers (3%) find the courses way too hard or easy.

Key outcomes to date

If the typical course-taker is likely to be an experienced secondary teacher enrolled for personal interest, who brings some science background but less experience with distance learning**,** and who generally has a positive experience in the course -- then what contribution do the courses make to course takers? In this section we include survey data, as well as three "Cases of Course Usage and Impact," based on recent interviews with teachers who have taken several courses. These mini-case studies convey the various potential contributions of the courses to teachers for whom the courses were designed.

Teachers tell us that the courses strengthen their personal relationship with the discipline.

On the end-of-course survey participants report that:

- The course(s) added to their own personal knowledge (91%) and provided a bank of resources they can draw on for their own learning (83%)
- The course-taking experience gave them deeper insight into the work of scientists (76%)
- The experience rekindled their passion for science and the work of science (74%)
- They are motivated to learn more about the course topics on their own (72%) and to take more science classes (67%)
- Their work in the class makes them more of a science expert from the point of view of colleagues (35%).

Course takers also tell the guides and scientists directly about the courses' value. A guide who has led several different courses and is a classroom teacher himself told us that:

> . . . the outpouring of accolades from the learners tells me that we are reaching our audience and providing them with a very valuable service. I guess that is the best thing for me – we are providing teachers a type of knowledge that is difficult to get in such a concentration in any other manner.

And scientists themselves observed the engagement of teachers with the courses:

> I have taught geology to elementary teachers before, so my expectations of the students were not high, to say the least. But in general they surprised me by their motivation, desire to learn, and amount of material they seem to have picked up.

The courses enable teachers to bring more to their instructional relationship with students.

In addition to sharing newfound or rekindled enthusiasm for science with students, teachers bring back to their students:

- new kinds of media and materials (77%) and other new resources (71%) they can use in science
- new content (72%) and learning experiences that can serve as a good model for the kind of work they ask students to do (73%).

Perhaps most importantly, almost 3 in 5 of the teacher-participants (60%) say that their experience in the course(s) gave them an opportunity to show students that they too are learners and almost half say that student confidence in their teaching has increased (45%).

The teachers are also using course resources to connect their students to the discipline. Although the courses are designed primarily as adult learning opportunities teachers say that they are taking what they learned back to the classroom.

- 7 in 10 (71%) have used what they learned as background to create a lesson or unit for their students
- 6 in 10 (60%) have made some of the resources available to their students
- 5 in 10 have explored course resources and materials with their students (48%), or had students do some of the same investigations that they did (45%)

- A teacher we interviewed mid-course described how she thought her own experience in the Universe course would benefit her students:

> [The conceptual focus of the course] is less a factual focus than it is an exploration of where I am when I started and where I will be when I finish. If I can go through the ups and downs of deciding if or if not life is present, then I, as teacher, can guide my students along this same path. This “trip” is necessary because the topic of life on other planets is so popular—should it be popular or should it be a scientific problem to be investigated and scrutinized, supported with facts?

- One of our own course reviewers commented on some of the reasons that teachers are applying what they learn in the course to their classrooms:

> For at least one assignment [in Genetics], the participants were asked to consult a website that contained a database of genetic information. This use of “authentic” scientific data is a great opportunity for teachers, especially if the data contain information that is personally interesting or useful. In this case, the teachers were intrigued by the site and wanted to create a way for their students to access the information. This example illustrates the notion that as more and more scientific data appear on the internet, more opportunities for students and teachers to get a sense of “real” science become available. Courses such as this one are ideal for helping teachers find, work with, and think about ways to engage their students.

Cases of course usage and impact

Case #1:
Mr. A finds that the courses complement his Master's Degree program and enrich both his classroom and a collegial relationship

Mr. A, a 10th grade biology teacher from New Hampshire who took the Dinosaurs and Sharks courses, said that at first he was reluctant to try the on-line courses. He was skeptical that the on-line venue could provide as much quality interaction and practical applications as college courses. He was also enrolled in a Masters Degree program, and he thought that these courses might be a good alternative, though, to driving and the time-constrictions of on-campus courses. He thought these courses might complement his Masters coursework. He was pleasantly surprised.

> *It was everything I expected from a good course without the hassle of going to a college classroom. It was great to be able to do the courses on my own time. Both of the courses I took gave me something to bring back to my classes.*

In his biology classes, he had done sections on birds and sharks in the past, so he found these SOS courses "really fit well into what I was already doing and enhanced it." He brought back specific activities from the courses and used them with his students. For example, from the Dinosaurs course, he had his students analyze similarities between theropods and birds. He also found the course CDs very useful:

> *…both for my personal reference, but also I shared them with my classes, they became very valuable tools for us. I showed students a lot of what I was doing in these courses. Next semester I'll build on it more and use even more of the resources.*

Like many other SOS participants, he created classroom lesson plans for his projects in both courses and was able to use them.

> *I took those right back and used them with my students. I ran them by my advisor first and he thought they were fine. They worked out well. They needed a little sharpening around the edges, but kids were receptive.*

One unique aspect of this participant's experience was that he took a course along with a colleague from his school. They were able to meet regularly and share thoughts and questions about the course.

> *Meeting and talking about the course, that was good. He [his colleague] was very interested and knowledgeable about dinosaurs. We'd share ideas and resources, and the excitement about what we were learning.*

In summarizing his feelings about the courses overall, this participant said:

> *These courses help keep me current, which is so important in education . . . also my interest increased, my interest in these topics. I'm looking forward to taking other courses, if possible. These courses are a lot easier to incorporate into my busy schedule and they are cost effective.*

Over half of the teachers taking the courses think that their participation in the courses strengthens their students' relationship to science.

- 6 in 10 say that it has increased students' appreciation for the natural world (58%) and helped students connect science in school to the real world (58%)

- 5 in 10 believe that the courses pique their students' curiosity about the course topic(s) (52%), makes the work of scientists more real and understandable to students (52%), increases students' knowledge about the latest research in the field (52%) , and increases students' understanding of the nature of scientific inquiry (49%)

Not only do teachers believe the quality of SOS courses is inherently high, but teachers also find them to be more valuable than other learning opportunities available to them.

- More than 9 in 10 (95%) say they would recommend the courses to colleagues

- Of those participants who could compare the courses to other professional development, 8 out of 10 say that the AMNH courses are better than other professional development available to them locally (83%) and/or that these courses are more valuable than other distance learning courses they have taken (79%).

- 7 in 10 (69%) have already recommended the courses to colleagues

Teachers told us that they the courses were superior both because of the effort extended by AMNH staff, but also because of the effort they demanded of participants:

> Some of my favorite professional development has been in-person, in classrooms, but as far as the ultimate product that I had to produce, these courses were the best. The lesson plans I created were so useful. Someone thought a lot about how to tie those six weeks together and how to get people's interest and build on it. And I'm using that back in my classroom.
>
> The way the facilitators actively participate is fantastic. In other online classes there is often a 'dumbing down' to the lowest common denominator, you're not encouraged to do your best. The AMNH people treated it as an upper level class, they treated us like adults without

intimidating anyone. They encouraged everyone. They are really good at that.

I've done other online courses where the mode is to whip off answers, but this required the kind of effort where you have to apply yourself. A lot of professional development is fluff, necessary to get credits to satisfy requirements, but this is genuine content, not fluff.

Cases of course usage and impact

Case #2: Ms. S gains what she needs to enhance science instruction of an elementary gifted class

Ms. S, an Elementary gifted-class teacher from Kansas, took the Universe and Genetics courses. She enjoyed the courses tremendously, and especially appreciated that they focused on questions, dealt with controversial topics, and were content oriented.

> *There was a wealth of information provided for different participants' levels of understanding and background.*

When asked about her motivation for taking the courses, she responded:

> *It fit so well with what I wanted to do in class with my students. I felt it would give me the background to do some new things in class, to get information from experts and to learn about resources I could use in class.*

Indeed, she felt that the courses made a big impact on her classroom. She used the courses as background and as a knowledge base for her teaching. She implemented the lesson plans she had done for course projects. She created online activities for her students and utilized the course CDs as resources in her classroom. In terms of the Genetics course, she found it to be a particularly interesting and relevant topic for her students. She said:

> *It worked very well. We had a local parent who worked at a large genetics center invite my 5th and 6th grade students there. I felt more prepared because I'd taken the class, and felt able to interpret for the students what we saw and heard.*

These courses provided learning opportunities that this participant valued greatly, especially in terms of their quality, depth and usefulness. Comparing these courses to other professional development opportunities, she said:

> *I take workshops through the district, but have done most of my professional development at state and national conferences. With the AMNH courses, you have to practice, you have to work through the ideas and communicate with other people. It's the time element that's different, it's extended over time. Most conferences also don't have you do a complete project that you can take back to the classroom, unless they offer college credit. Also, at conferences I'm dealing with educators who are not necessarily in-depth about their topic, whereas with these courses, you're talking with other motivated teachers and experts, leading scientists in the field.*

Summary

We have studied many projects, including many in math and science that endeavor to provide professional development to teachers. Often we see projects that emphasize ways to help strengthen the link between the student and the discipline, but do not deepen the teacher's own content knowledge or relationship to science (e.g., professional development around structured use of science kits or curriculum materials). Other projects focus on deepening teachers' content knowledge, but do not model learning experiences that translate to the classroom. Other times, we have seen good professional development delivered to a teacher audience that is not able to benefit from it because their prior knowledge is weak or because they are a captive audience at required staff development sessions, etc.

These courses strike us as having particularly strong potential for making a contribution to science teaching and learning because both the courses and learners have the particular characteristics that we have described, and because there is a good match between the courses and the learners. Thinking again of the relationship triangle, we see that in general, the learners already have a relationship to science, and the courses have the potential to deepen that relationship. Moreover, the courses provide the kinds of experiences and information that teachers want to share with students and that students find engaging, giving the courses potential to strengthen the second leg of the triangle, the teacher-student relationship. And students are able to benefit from what the teachers share – content and scientific aptitudes and attitudes, making the third leg stronger as well.

Cases of course usage and impact

Case #3:
Ms. P. finds a professional community beyond her high school in rural Mississippi

Ms. P, a high school science teacher from Mississippi, has taken five Seminars on Science courses (paid for by the state). When asked about her motivation for taking the SOS courses, she replied:

> *Taking online courses was new for me. I was first drawn in by the idea because this is a rural state and there's not a lot of interaction professionally. I thought this would be a way I could feel that I was still learning something and connecting to others in a learning community. I don't need the professional development credit . . . I take the AMNH courses because I learn a lot, and I like the idea of learning at my own pace.*

One thing she likes about the courses is that "you have some connection to a person who is a researcher." She feels that is a rare experience, "unless you are taking a university course, and full-time teachers don't have time to do that." She also feels that quality materials were used in the courses:

> *The resources are the best! They expect you to do readings in primary sources, not just on websites. It's very challenging and well done.*

Although "picking up a few more computer skills" was not a top priority for her, she mentioned that it as a side benefit of taking the courses. Her primary purpose in taking the courses, she emphasized, was

> *. . . to find things I could actually translate for use in my classes. I wrote my project lessons so I would use them, and I made them fit our state and national standards.*

In her classroom, she indeed used her project lessons, and in a few cases she has used them more than once. She has changed them a little, for example by incorporating facts she picked up along the way from other resources such as videos, books, and articles. She said that the SOS courses led her in the direction of searching out new material. She also adapted many of the same investigations from her SOS courses and used them with her students. She was even inspired by the courses to write a few grants for special classroom projects. One grant, inspired by the Fishes course, was for an aqua-culture-based project for her students and a group of special education students.

> *We [in this region] are number one in the country for heart disease. I wanted kids to know that aqua culture here is big, and to learn about heart-healthy seafood dishes. We ended up being able to buy water testing kits and catfish products, produced locally, and the students made heart-healthy lunches. It was new to them, because around here we have old-fashioned cooking. Also, our kids got to understand those special education kids better, as well as some of the science about fishes.*

Finally, the AMNH courses helped prompt and prepare her for seeking and obtaining national board certification. She explained:

> *Having taken these courses helped me, two years ago, on my national board application, and I got it! The courses helped pique my interest in learning new things again and trying new things like trying for the national board certification.*

IV. THE SOS PROJECT AS A MODEL OF "EDUCATIONAL ENGINEERING" FOR INNOVATION

While the SOS project aims to provide direct service to teachers, we believe the SOS project is best understood at this stage as an educational "engineering" project. Innovation in education rarely comes about through a long-term, deliberate and iterative process as has become standard practice in many other fields. The approach taken by the AMNH in developing its SOS is unusual in the degree to which it resembles an engineering R&D model. We believe that the considerable contributions that the SOS makes at the intersection of professional development, online learning and science-rich institutions – along with its contributions to participants -- are due in some large part to the AMNH's process of course development and prototyping. Therefore, we conclude this report by explaining what we mean by educational engineering and how the AMNH SOS project is pursuing its work along those lines, with the hope that others may draw upon and benefit from their experience.

What is an engineering approach to innovation?

When GM or Ford, for example, wants to develop a new and innovative car (e.g., an electric hybrid car), it undertakes a process of research and development involving several carefully structured stages of engineering.

Engineering involves design under constraint. Its stages reflect, roughly, the following steps:

1) Identification and clarification of the design problem to be solved or the challenge to be addressed.

This process involves becoming clear about the intended outcomes, goals, and vision for the project, as well as the challenges and constraints the problem presents. Often goals are stated in terms of multiple dimensions that one wants to optimize or minimize. (For example, GM might like to design a car that is very energy efficient, safe, has satisfactory power, and the maximum volume possible.) Often some dimensions of the design are given higher priority (e.g., high gas mileage and low fuel costs).

2) Examination of current theory and of current practice.

Engineering – as a systematic process of research and development — seeks to build upon – and improve upon – what is known. An engineering design process will draw upon all the available scientific theory, pre-existing models, evaluation of previous experiments, and existing products and practices.

3) Inventing design conceptions.

Here the project designers begin to imagine solutions that would address the problem or challenge. Some of these solutions are holistic; others only address part of the problem. (One might conceive the form of the vehicle to be designed; other engineers might simply think about optimizing the design of the transmission.)

4) Proof of Concept.

Very often designers will try to instantiate a design concept by creating a very rough mechanical analog – a kind of "draft prototype." In testing this very rough initial creation the designer seeks to show that the concept is viable. No effort is made at this point to argue that the model that is produced is in anyway the model that will work in the real world. (The Wright Brothers in flying at Kittihawk produced a draft airplane that was a compelling proof of concept if not a commercially viable aircraft!)

5) Assembling and testing prototypes.

Eventually, one begins to construct simple but valid prototypes of the ideas that seem most promising. These prototypes are then tested in more or less laboratory settings (e.g., for cars, wind tunnels) and / or in a few carefully selected real world settings, so that engineers may learn the extent to which their conceptions and theory are achievable. They study the prototypes with the express purpose of validating their continued feasibility, and with the purpose of improving the prototypes in the next iteration.

6) Beta testing and scaling up.

Once an idea has been shaped, through repeated testing, into a product that appears to work in real conditions, the innovation is ready for the next phase of testing which involves more diverse settings and naturalistic usage. Here the designers discover whether or not users who are not familiar with the product can use it successfully, and what kinds of supports and training are needed. In this process the designers discover all the unforeseen pitfalls and problems that earlier tests have not uncovered. And they begin, also, to have a sense of the key dimensions that will ultimately affect the marketability of the product.

7) Large scale marketing, dissemination, and ongoing revision.

The product, if it is successful to this point, goes to market. The designers hope, of course, that it is used widely.

Research needs to be done even after this stage so that the product design can continue to evolve in future models or versions. Large-scale usage allows for independent studies that can be used to further evaluate the product and inform consumers.

In summary, an engineering process allows for an iterative set of steps in which design, testing and revision occur and recur. Each step allows the product to evolve as well as contributing to cumulative knowledge of the product's overall value and effectiveness.

By contrast, education is a field where an engineering R&D approach has not become the standard approach to innovation. Typically, educational innovators craft a version of their idea, which they and others treat quite immediately as final or near final. The developmental process around educational innovation is usually constrained by incomplete theories, shifting policies and short-term funding cycles, as well as public pressure to go to scale quickly. Thus, in best cases there is some formative field testing and revision, but it is not long before there is pressure "to scale up" the innovation for wide scale usage.

The table below contrasts education with other fields more fully developed in their R&D capacities and commitments:

Figure 5.
Comparison of R& D capacities and commitments typically found in the fields of engineering and education

Engineering Research and Development	Educational Research and Development
Multiple successive stages of design, testing	One or two stages of design, testing and revision
A long, deliberate development process	A short, possibly idiosyncratic development process
Assemblage and testing of components	Holistic design
Careful study of and learning from prototypes	Little use of prototypes
Summative evaluation conducted after many testing and revision cycles	Summative evaluation after limited formative evaluation
Scale up done slowly and after extensive development	Rapid scale up
Clear goals and explicit design criteria	Design criteria that are less clear than goals
Basis of further refinement	Lacking knowledge of the innovation, others in the field reinvent without benefit of the knowledge accrued by the innovators

The approach of the AMNH in developing its courses

Below we offer an account of the AMNH's development and testing of the new courses, and identify where in the engineering process they stand at this point.

Developing a broad goal[10]. While the AMNH has historically played a role in supporting formal K-12 science education, the bulk of its educational work lay in the domain of informal education. However, several years prior to the inception of the SOS project, the museum undertook its first initiative to formalize its support for teacher preparation and professional development. In part, the Museum's framing of this goal was a response to the call to action— proposed by

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[10] This section draws from our own observations over four years as well as a thoughtful and more detailed accounting of the development process for the SOS courses, set in the context of other recent AMNH efforts to create formats for providing instruction and resources to teachers: A Science Museum's Expedition Into the World of Formal Teacher Development: First Three Years of a Five-Year Action Research Study (presentation at AERA annual meeting, April 3, 2002 by Maritza Macdonald, AMNH, Heather Sloan, Lehman College and Eleanor Miele, Brooklyn College, City University of New York).

the National Commission on Teaching and America's Future: What Matters Most—to "take on the difficult work of developing teaching of ever higher quality" (1996, Summary Report, p.29).

Amassing capacity related to the goal. The museum then undertook a set of experiments designed to advance their own knowledge about science teacher learning that takes place outside of the formal higher education institutions; these included development of school partnerships and inclusion of teachers on scientific expeditions.

The AMNH also created a new higher education team for teacher development as a new way for the museum to approach professional development. The Education Department brought scientists into the department to work directly with educators in collaborations of professional development. Scientists contributed content expertise. Teacher educators shaped professional development days, courses, and institutes to meet teaching standards for certification and licensing. Teachers brought their experience with using museums for instruction. Educational technologists joined the technology arm of the education department, the National Center for Science Literacy, Education, and Technology (NCSLET). This center is charged with creating Museum programs and products to bring the Museum scientists, their research, and the exhibitions beyond Museum walls. This team was a new and unprecedented museum asset, one with the potential to bring wide experience and expertise to defining and solving a problem that was, as yet, only broadly and generally defined – to design and implement new programs for teachers.

Specifying the design challenge. The Higher Education Team for Teacher Development and others at the museum spearheading education initiatives drew from key reports and policy developments in formal education to identify several dimensions of the problem they wished to address, including content and content standards, best practices for teaching and learning, and professional development practices and standards.[11] Additionally, they decided to make new education programs available to teachers at a distance; and decided further that the new courses would draw from the unique and rich assets of the AMNH as a world-class science institution.

[11] These included: 1997 reports from the National Center for Educational Statistics (NCES) on the US performance on Third International Mathematics and Science Study (TIMSS); the Council of Chief State School Officers (INTASC)'s blueprints and work on teaching standards; the National Board of Professional Teaching Standards (NBPTS, 1997) for certification of highly qualified teachers; and the science learning standards and benchmarks disseminated by the National Research Council (1996).

Drawing both from the concerns of the "market" that they hoped would use their product (the formal education system) as well as from their own assets and innovative desires, it was at this stage—1998-99—that the AMNH defined more specifically the goal that led to eventual development of the SOS program. In the words of their original funding proposal:

> *The goal is to design and implement a technology-based model for professional development, one which makes use of distance learning and other telecommunications to build a thriving learning community for teachers…. To draw upon the Museum's collections, communicate the topics of current scientific research, and leverage the knowledge gained from the development of major new exhibitions … To develop inquiry and object–based science education materials and activities….*

<u>Building on existing knowledge</u>. The Museum staff continued to study standards documents and other reform resources to enhance their ability to design a series of courses that would satisfy the market. Additionally, AMNH staff commissioned us at Inverness Research to help gather existing research- and practice-based knowledge about the several dimensions of the problem area (e.g., adult learning of content, on-line learning, teacher professional community), both from published literature and from leaders in the field.

<u>Conception of the "solution"—first steps in designing courses</u>. The AMNH staff then held a multi-day design retreat to synthesize existing knowledge and begin conceptualizing the structure and content of an on-line science course for teachers that drew from AMNH resources. They further framed course goals: e.g., they wanted teachers to increase their knowledge of science content and of science resources and how to adapt them; to understand the nature of science as inquiry and as interdisciplinary; to increase their capacity to develop environments for student inquiry; and to reflect on their teaching practice.

They also conceptualized a course invention and development process that involved scientists, educators, and production experts in very different roles and that required close collaboration. Further, they made an important decision not to construct the technical platform for distance learning but to build their courses onto the existing platform of Connected University[12]. With each aspect of the conceptualization, they further refined the design opportunities and constraints.

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[12] Connected University (http://cu.classroom.com) offers distance learning courses for K-12 educators under the umbrella of Classroom Connect, a business unit within Harcourt, Inc. It offers 65 courses (including those produced by AMNH) in math, reading, science and social studies, as well as in technology, assessment and educational leadership. Graduate and CEU credit are available through 5 colleges and universities, as well as the Mississippi DOE.

Building the first prototype. Teams of production staff, scientists and educators then devoted several months to creating the first prototypes, taking course plans through iterative design-and-review processes to create the building blocks of the 6-week courses—the assignments, resources, and experiences that would be built into courses to achieve the goals. Museum scientists and curators authored the courses, drawing from their own research and the collections at the Museum, but the content was also organized to reflect the content standards of the marketplace. Teacher educators, scientists and technical staff met very frequently, as both the courses and the production processes evolved through the building process.

Feasibility proof. In spring 2000, the first set of 3 courses (Fishes, Mammoths, and Spiders) was rolled out. All aspects of the course were monitored closely. The course team and project managers met weekly. Scientists, guides and education staff sometimes jointly fashioned responses to participants. Local teachers and museum staff were recruited to be participant-observers. Inverness Research staff took the courses as well. Inverness conducted focus groups with scientists, guides and learners mid-course and at the end of the courses.

This first set of courses did, in fact, prove the viability of the concept. (Up to this point, it was not a certainty that the course could be conducted successfully as designed.) Based on lessons learned in the prototyping, staff made substantive changes to these courses - clarifying expectations of learners, remedying technical glitches, reducing the course load, and refining strategies for facilitating online communication with learners. To the extent possible, given their development schedule, they also applied what they learned to courses still under development.

Prototype testing and refinement. In Fall 2000, the second round of prototypes were tested. Two of the original courses were repeated (Fishes and Mammoths), and two new courses (Earth and Universe) were added. This new pair of courses differed from the original three in that they were developed in conjunction with new halls at the museum, and relied less on than the first set on the specific research conducted by the authoring scientist that was at the heart of the first round of courses. All aspects of the courses were again studied. SOS program managers refined their documentation of the courses, tracking for example, quantity and quality of participation. Inverness recruited course takers from the national pool to provide feedback at several points in the courses and continued themselves to monitor the courses.

This iteration of testing produced new knowledge. First, the courses remained equally interesting to course takers and nearly all the scientists, even through the many changes in them. Second, the courses were dramatically improved from the first round in terms of workload, technical aspects, and course navigation. Third, one AMNH scientist found that he did not find teaching in this context rewarding; this meant that a course was dropped but it also meant that the staff learned more about the conditions of scientist involvement.

By Winter 2001—less than a year after it had offered its first course—the SOS group had developed considerable capacity to mount courses. During this third round of courses the project continued to consolidate its strengths and identify new areas for growth and refinement. For example, the project stretched itself by offering six courses at once, including a new course (Sharks). To do so, it needed to identify and train a broader guide pool, and engineer changes in membership of course leadership teams. Based on lessons learned in early courses, it developed a strategy of teaming new guides with experienced ones when possible. Along with Inverness Research, it studied the role of guides intensively during this period. It also began to invite friendly teacher educators from local colleges to audit the courses to help the museum think about their possible usefulness and role in teacher preparation. And it began to collect feedback from course takers in general through online and email surveys of course takers both mid-course and at the end of the year.

Through these rounds, enrollment remained small. SOS staff made some efforts to increase awareness of the courses and enrollment, but relied mainly on CU to attract new learners. Multiple sections of learners never materialized, though, which meant that the staff did not have an opportunity to test the courses under that condition.

During the last rounds of prototyping—multiple courses from Fall 01 to Summer 02 —SOS premiered its 8th course (Dinosaurs) and began to regularize and institutionalize the courses themselves, the production processes, and the course review and refinement processes.

The table below summarizes how many times each course was offered. Refinements to any one course also added to the collective wisdom contributing to refinements to others.

Figure 6.
SOS course offerings to date

Courses offered each quarter	Round I: May-July 00	Round II: Fall 00	Round III. Winter – Spring 01	Round IV: Summer 01	Round V. Fall 01	Round VI: Winter – Spring 02	Round VII: Summer 02
Dinosaurs					X	X	-
Earth		X	X	X	--	X	-
Fishes	X	X	X	X	--	X	-
Genetics			X	X	X		X
Mammoths	X	X					
Sharks			X	--	X		-
Spiders	X	--	X	X	--	X	-
Universe		X	X	--	X		X

At this stage after multiple rounds of offering and monitoring, all but one of the courses is essentially "finished," and the last revision will be completed this winter. The staff have not solved every problem with the basic structure of the courses: They continue to grapple with real challenges of how to elicit high-quality learner participation in courses and to assess learning. Several authoring scientists have handed over their courses to other scientific staff at the museum, and there are still some rough edges to these transitions. Response rates to our surveys are lower than SOS and we would like[13]. However, the SOS leadership has been notable throughout the project for its tenacious commitment to learn from its experience, and we have confidence that they will meet these challenges just as they have met others.

<u>The next step: testing in new environments</u>. The project has finished the first prototype phase and is entering a four-year period of beta testing in which the refined courses will be offered in a range of different educational environments and conditions. Lessons from this phase will lead to strategies for scaling up the courses so they reach a broad market. We discuss this further in the final section of the paper.

[13] We have noted that survey response rates seem to be declining for many projects over the last few years. In addition, SOS participants may be so busy with the courses that they do not find time to complete the mid-course survey.

Summary

Unlike some other industries, education does not have a set of agreed-upon norms for the development of innovative products and approaches. We believe the approach that the AMNH is using to develop the SOS courses resembles the kind of careful design and engineering that takes place in other fields. Ironically, premature effort to take an innovation "to scale" before it is well tested can undermine the quality of the innovation, thus reducing its chances of spreading and surviving. The slow and deliberate approach of the AMNH means it is more likely to produce a robust innovation that will succeed in the real world and, perhaps, endure longer.

The fact that other developers around the country are, simultaneously, inventing ways to offer teachers professional development opportunities at a distance has further implications. There has always been distance learning (e.g., correspondence) courses, but the type that SOS represents are part of a new wave of innovation in which multiple inventors are working in multiple domains on a general problem in a field. There is likely to be considerable synergy, with many solutions surfacing that have features that are both distinctive and similar. For example, the AMNH courses may be similar to those of a research university in the quality of the content and instruction; however, the SOS courses will have a different flavor because they reflect the culture and resources of an informal institution that has 100 plus years of educating the general public and educators about science. The SOS project's multi-year, multi-step approach affords them enough time to build from others' experiences as well as their own.

Recognition of SOS course quality by the field

These courses have gained national recognition with distinguished awards from the Association of Educational Publishers for Education Technology. In 2001, they were also selected as one of the technology and education initiatives featured at the National Education Summit co-sponsored by IBM and Achieve, Inc.

V. TOWARD THE NEXT PHASE OF DEVELOPMENT

The first phase of this project has demonstrated the basic feasibility of the courses. As is to be expected in this kind of engineering project, the development of the eight courses has been labor intensive; also, the courses have reached relatively few teachers (at least when viewed on a national scale), serving only those individuals who encounter them through CU and who choose to enroll.

There are still some areas in course implementation that will need further refinement in the next phase of the project, such as learning how to manage multiple sections of a course, assimilation of new scientists and guides as course leaders, motivating and helping more learners to use everything they are gaining from the course in their online postings, assignments and projects.

The project now faces the larger challenge of learning how to make the courses (in their current form or as an adaptation) available more broadly. Another way to frame the question is: Can the project take the next step toward a more systemic contribution to science education?

There are several ways to envision a more systemic context for teachers' access to and use of the courses. Perhaps one of the NSF Systemic Initiatives could use SOS courses as a component of the professional development they provide. Perhaps there are school or district professional development programs that would like to incorporate SOS courses into their work. Perhaps university teacher preparation programs could use these courses as part of their credential programs. Theoretically, any of these institutions could use SOS courses in whole or in part.

We do not recommend a specific approach to disseminating what the SOS project has created, nor do we mean to simply list possible usages of the courses. Rather, we recommend that the AMNH invest considerable effort in engineering new ways to make these courses and materials useful and available to educators. Dissemination and usage will not occur automatically, no matter how good the courses are. In fact, we believe the project will have to work just as hard at engineering usage in other contexts as they did in developing the courses.

Thus, we see the SOS project as having the following goal for phase II (in addition to continuing to refine the courses as needed): to learn how to conduct new experiments in which the SOS model is adapted and tested in a few wellchosen and carefully engineered pilot settings. These "new usage" experiments will involve, among other things, helping to train people in other institutions to offer the courses, and helping to infuse the courses into other existing projects and institutions. These experiments will necessarily involve creative collaborations in which SOS staff work with other faculty and reform leaders. These experiments will seek to show that the science-rich courses developed by AMNH can, in practical ways, serve teachers who are taking the courses not independently, but under the aegis of other projects. There is a whole new set of design challenges involved with this more "wholesale" mode of delivery, and a whole new set of lessons to be learned.

In some sense, we might regard the first phase of this project as having succeeded in showing the "internal validity" of a new model. That is, AMNH has shown that they can indeed create both rich and practical learning experiences for teachers. Following on this success, the AMNH now faces an equally challenging task—to begin to show the "external validity" of the model. The project will demonstrate external validity when this model can connect with and fit into the rest of the world, i.e., when there are established approaches for helping others use the courses and materials; when the courses and materials serve multiple educator audiences effectively; when the courses can function—politically and educationally—in a range of settings.

We do not see the second phase of the project as necessarily resulting in large-scale usage or achieving cost efficiency. Just as the first phase consisted of a few careful rounds of course offerings, so the second phase should also consist of a few careful experiments in usage. Once the project has shown that it can develop courses (first phase) *and* that it can find different feasible ways to fit the courses into the world (second phase), only then is it appropriate to take on the challenge of truly scaling up and achieving greater cost efficiency (third phase).

THE AMNH *SEMINARS ON SCIENCE* PROJECT:

LESSONS LEARNED FROM PHASE I

1999-2002

APPENDICES

A. Description of courses

B. Enrollment and course completion data (1 table)

C. Surveys of course takers

1. Mid-course survey results

2. End-of-course survey results

D. An independent review of AMNH Online Seminars by Metacourse, Inc.

Appendix A.

The Seminars on Science Courses: Course Descriptions and Key Science Concepts and Processes

Dinosaurs Among Us: The Link to Birds

Course description (as presented on the CU website to potential participants): One branch of the dinosaur family tree did not go extinct. Today, we call them birds. In this course, learners examine and discuss fossil evidence that links theropod dinosaurs to modern birds, examine several theories about causes of the K/T extinction 65 mya, and investigate the origin of birds.

Key Science Concepts and Processes (as presented on AMNH website):

- Biological evolution
- Biological classification
- Extinction
- Geologic time
- Examine evidence, interpret and analyze data, and draw conclusions

Diversity of Fishes

Course description: This investigation-based life science course introduces learners to the incredible diversity of fishes. By going behind the scenes at the Museum, learners explore the biodiversity of fishes and see how research scientists use the process of systematics to identify, describe, and classify species.

Key Science Concepts and Processes:

- Biological diversity
- Biological classification: taxonomy and systematics
- Make observation, examine evidence, interpret and analyze data, and draw conclusions.

Earth: Inside and Out

Course description: Earth scientists, working under the premise that the present is the key to the past, make observations and examine evidence about our dynamic planet. Learners explore Earth science concepts such as time, change, convection, and investigate research on the climate, plate tectonics, and deep-sea vents.

Key Science Concepts and Processes:

- Earth as an interconnected system
- Change
- Plate tectonics
- Climate
- Make observations, examine evidence, interpret and analyze data, and draw conclusions

(continued)

Genetics, Genomics, Genethics

Course description: The Human Genome Project … cloning … genetic modification? These terms dominate the news today, but what exactly do they mean, and how will they affect our lives now and in the future? This investigation-based life science course explores the potential implications of the evolving field of genetics.

Key Science Concepts and Processes:

- Heredity
- Genes and the environment
- Science and technology in society
- Make observations, examine evidence, interpret and analyze data, and draw conclusions.

How to Think About Life in the Universe

Course description: The question of life in the universe is one of the most intriguing intellectual conversations of our times, but it is hardly new. Learners will explore astrobiology and review the basics of astronomy and astrophysics. By course end, learners will have a toolkit for thinking about this question.

Key Science Concepts and Processes:

- The structure and evolution of the universe
- Habitable zones
- Interpret and analyze data and draw conclusions

Sharks and Rays: Myth and Reality

Course description: Long able to capture the imagination, sharks are one of the most recognized fishes in the water. Surprisingly, the ray is one of their closest relatives. Learners join a Museum scientist to explore fossil and living sharks and rays, and consider issues of shark conservation.

Key Science Concepts and Processes:

- Diversity and adaptation
- Anatomy and morphology
- Fossil evidence
- Interpret and analyze data and draw conclusions

The Study of Spiders

Course description: Did you know you are never more than six feet away from a spider? Spiders, both fascinating and frightening, are master spinners and voracious predators. Through direct observations, this course guides learners in the collection, description, and identification of spiders.

Key Science Concepts and Processes:

- Species diversity
- Anatomy and morphology
- Biological classification
- Make observations, interpret and analyze data, and draw conclusions

The AMNH also developed and twice offered another course, Why are There No More Woolly Mammoths? It is no longer offered.

Appendix B.

Course enrollment and completion data

		Enrollment data						*Completion data*[14]					
Round	*N of courses*	General learners	Ind. learners	CEU	Grad hours	Total (cols 1-4)	*(Auditors - not counted in completion rate)*	General learners	Ind. learners	CEU	Grad hours	Total (cols 1-4)	*Completion by round*
I. May - July 00	*3*	34	4	8	0	**46**	*0*	20	1	3	0	**24**	***52%***
II. Fall 00	*4*	48	2	1	0	**51**	*11*	24	0	1	0	**25**	***49%***
III. Winter 01	*6*	113	23	3	2	**141**	*44*	65	12	4	2	**83**	***59%***
IV. Summer 01	*4*	46	7	7	5	**65**	*23*	22	1	6	3	**32**	***49%***
V. Fall 01	*4*	67	6	3	6	**82**	*14*	21	1	3	5	**30**	***37%***
VI. Winter 02	*4*	82	10	0	6	**98**	*34*	46	1	0	6	**47**	***48%***
VII. Summer 02	*2*	46	1	2	4	**53**	*5*	26	0	1	3	**30**	***57%***
Total for Rounds I-VII	***27***	**436**	**53**	**24**	**23**	**536**	***131***	**224**	**16**	**18**	**19**	**271**	***51%***
							Completion by enrollment status	**51%**	**30%**	**75%**	**82%**	**51%**	

[14] The average completion rate for SOS courses is roughly comparable to the typical course completion rate for CU courses, which are generally less rigorous. Retention rates for online college and university courses are generally in the 60%-80% range. Interestingly, in the Concord Consortium's online course for teachers on the pedagogy of inquiry, 74% of participants earning CEUs completed the course, virtually identical to the SOS retention rate for SOS course takers earning CEUs. Several sources indicate that retention rates tend to increase after courses are revised based on course taker feedback; when we examined retention rates for SOS courses more closely during round III, we found that the courses that were repeated had higher completion rates after they were revised for later rounds.

Appendix C.

Surveys of course takers

1. Mid-course survey results

2. End-of-course survey results

Appendix D.

An independent review of AMNH Online Seminars by Metacourse, Inc.