Virtual DUSEL (vDUSEL)
The Online Educational Project for Sanford Center for Science Education

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Abstract:

Planning for the Deep Underground Science and Engineering Laboratory (DUSEL) is under development at the former Homestake Mine in the Black Hills of South Dakota. This will be the next national laboratory in the United States. Many will not be able to visit DUSEL but will be interested in what occurs there. This includes researchers, teachers, students, and the general public. Virtual DUSEL (vDUSEL) is the Sanford Center for Science Education's (SCSE) online distance effort and has been tasked with developing innovative approaches for the delivery and support of E&O related to the Sanford Lab and DUSEL. The goal of Virtual DUSEL (vDUSEL) is not to bring interested parties to an education outreach website but rather to bring them to DUSEL via the web; providing the experience that "*you are there*" to people who *can't be* there physically. This paper investigates the issues related to the development of vDUSEL.

Introduction

Planning for the Deep Underground Science and Engineering Laboratory (DUSEL), is under development at the Homestake Mine in the Black Hills of South Dakota. This will be the next national laboratory in the United States. The effort to establish DUSEL has been an international collaboration led by P.I. Dr. Kevin Lesko of Lawrence Berkeley National Laboratory and Co-P.I. Dr. Bill Roggenthen from South Dakota State School of Mines and Technology. The state of South Dakota has played a key role, investing over $100 million to rehabilitate the mine and to bring an interim suite of experiments online. T. Denny Sanford has been a strong supporter, enabling the efforts underway at the Sanford Underground Laboratory (the state funded interim lab), and the Sanford Center for Science Education (SCSE). Homestake Mine has already been the site of Ray Davis's Nobel prize winning research on solar neutrino flux, and experimenters will use Homestake mine's great depth to make advances in physics, geology, engineering, and microbiology.

Many will not be able to visit DUSEL but will be interested in what occurs there. This includes researchers, teachers, students, and the general public. The goal of Virtual DUSEL (vDUSEL) is not to bring interested parties to an education outreach website but rather to bring them to DUSEL via the web; providing the experience that "*you are there"* to people who *can't be* there physically. Virtual DUSEL will be, in part, an organization of immersive virtual environments that allow visitors to experience the various aspects of the underground laboratory. For example, visitors will be able to ride a virtual elevator down to the various labs. As they descend they will learn about the geology of the mine, the environmental conditions and why the various labs are located at each level. Upon arriving at the desired depth, visitors will be greeted by a laboratory scientist (short video) who explains the nature of the experiments done in the lab and why they are located underground. Visitors will have the option to learn more about these experiments or they can move on to another level. If they choose to learn more, they can select from among in-depth videos, tutorials, animations, or simulations, where they may observe or conduct virtual experiments. They will be able to manipulate equipment, then collect and analyze the data, all based on the experimental facilities and data from the actual experiments. Visitors will also experience the science of the mine through virtual games, available for a variety of age groups. Both formal and informal experiences and materials will be provided, with curriculum materials will be aligned with national science and math standards. Beyond the immersive virtual environments, visitors will be able to experience DUSEL through live sensor and camera feeds and by viewing streaming videos of events and speakers. Visitors will also experience the science of the mine through virtual games, available for a variety of age groups. Both formal and informal experiences and materials will be provided, with curriculum materials aligned with national science and math standards.

Beyond games and immersive virtual environments, vDUSEL also comprises outreach and access for distance audiences of all sorts, including K-12 students, teachers, university students and faculty and researchers. vDUSEL and its virtual environments will be adaptive so that the experience will depend on the background, purpose and interests of the user. vDUSEL will promote and link to on-site DUSEL resources for tours, visits, and research experiences at the science center and lab. Kiosks for V-DUSEL can be located at science centers across the state and nation. Coordination with science centers will result in virtualization of physical displays and activities, along with physical realization of virtual activities. Large computational problems will become public projects; "DUSEL@Home" similar to SETI@Home and Einstein@Home and other distributed computing projects. Content management and social networking tools will provide for and encourage participation and collaboration among students, teachers and researchers, both limiting and supporting access based on interests and willingness to participate.

A crucial part of vDUSEL is to make it *easy* for scientists and researchers to participate, interact, and share with the varied audiences. Infrastructure, support and processes will be put in place so that every experiment and researcher can easily become part of vDUSEL. vDUSEL will require an organizational framework that is dynamic enough to allow vDUSEL E&O development to attract and accommodate a diverse collection of cross-cutting expertise while at the same time providing a well defined, cohesive, and accountable structure .

History

In the late summer of 2008, Dr. Stephen Krebsbach at DSU was asked by Dr. Lesko DUSEL-PI to bring together a South Dakota leadership team to drive the early planning and development of the Virtual DUSEL (vDUSEL) effort. The evolutionary vision for the vDUSEL effort is to begin by developing a collaboration of interested South Dakota regental institutions and supporting the capacity building of CI-enabled Educational and Research immersive environment developers, designers and researchers. Regental institutions in SD had little established expertise in this area though the newly state supported BS in Gaming at DSU was a first step to address this. The vDUSEL leadership team is currently made up of faculty from DSU and SDSU.

In September of 2008 at the University Round Table Discussion on DUSEL Research, Collaboration and Education held in Rapid City, SD, (a meeting to bring together SD university researchers, other SD stakeholders, and Berkeley personnel to discuss research collaboration opportunities between the groups) early vDUSEL plans were presented by the leadership team and gained support from all parties. In November 2008, the SD Board

of Regents funded a vDUSEL Symposium organized by the vDUSEL leadership team and hosted by DSU. This symposium brought together state, regional, and national participants with expertise in Serious Gaming and Immersive Environments development. It also brought in participants representing different state groups with interest in E&O efforts in the state. One important outcome from the symposium was the development of the formal Mission Statement and Mission Vision that would guide the development of the vDUSEL as it moves forward.

vDUSEL Mission Statement: *To share the wonders of the Deep Underground Science being done at the Sanford/DUSEL with those online and to excite and engage them in the active learning of science.*

vDUSEL Mission Vision: *The vision of Virtual DUSEL (vDUSEL) is not to bring interested parties to an education outreach website but rather to bring them to DUSEL via the web; providing the experience that "you are there" to people who can't be there physically. vDUSEL will be, in part, an organization of immersive virtual environments that allow visitors to experience the various aspects of the underground laboratory. This will include, but is not limited to, virtual tours of the underground laboratory, virtual lab experiments utilizing real data and educational games based on the science undertaken at the Sanford Lab and the DUSEL and grounded in state and national science education standards.*

Beyond games and immersive virtual environments, vDUSEL also comprises outreach and access for distance audiences of all sorts, including K-12 students, teachers, university students and faculty and researchers. vDUSEL will promote and link to on-site DUSEL resources for tours, visits, and research experiences at the science center and lab. Kiosks for vDUSEL can be located at science centers across the state and nation. Coordination with science centers will result in virtualization of physical displays and activities, along with physical realization of virtual activities. A crucial part of vDUSEL is to make it easy for scientists and researchers to participate, interact, and share with the varied audiences. Infrastructure, support and processes will be put in place so that every experiment and researcher can potentially become part of vDUSEL.

The vDUSEL effort has been adopted as the distance online presence of the Sanford Center for Science Education (SCSE) and DUSEL. It was presented as such as part of the E&O portion of the DUSEL S3 NSF Annual Review held at Berkeley in January 2009.

Although the state of SD has a strong interest in building the CI-enabled education and research development capacity within the state, vDUSEL, as a part of the SCSE and DUSEL, will need to evolve to include collaborations at not only the state level but also nationally and internationally. Another goal of the vDUSEL Symposium was to begin

the process of developing relationships with others outside the state with expertise in immersive education environments and who might be interested in becoming collaborative members of the vDUSEL.

VDUSEL Structure

Virtual DUSEL (vDUSEL) is the Sanford Center for Science Education's (SCSE) online distance effort and has been tasked with developing innovative approaches for the delivery and support of E&O related to the Sanford Lab and DUSEL. An important responsibility will be to coordinate vDUSEL with other E&O efforts by DUSEL, the State of South Dakota and other entities. Assessment of the overall vDUSEL will also be a strong focus.

Three leadership teams (Education/Virtual/Operations) will be created to help set the direction in their areas of expertise. Teams will be comprised of active researchers along with senior advisers (sages) and other technical experts (as appropriate). The goal of each team will be to promote and facilitate the overall efforts of the vDUSEL E&O research community at large. Teams will be directly answerable to the vDUSEL Administrative unit. An early effort by each team will be to identify specific projects and funding sources within their areas and as collaborative efforts with other teams. These teams are in the process of being formed, with collaborators invited from across South Dakota and across the nation.

Project teams will be formed with membership from among the DUSEL scientists and vDUSEL E&O researchers. These "bridge teams" will include: scientists -- content experts -- in fields such as physics, geology, engineering, and microbiology; researchers in learning and education; curriculum and assessment specialists; and software and multimedia designers. The vDUSEL core teams will provide people, access to data and other resources, and coordination for these efforts.

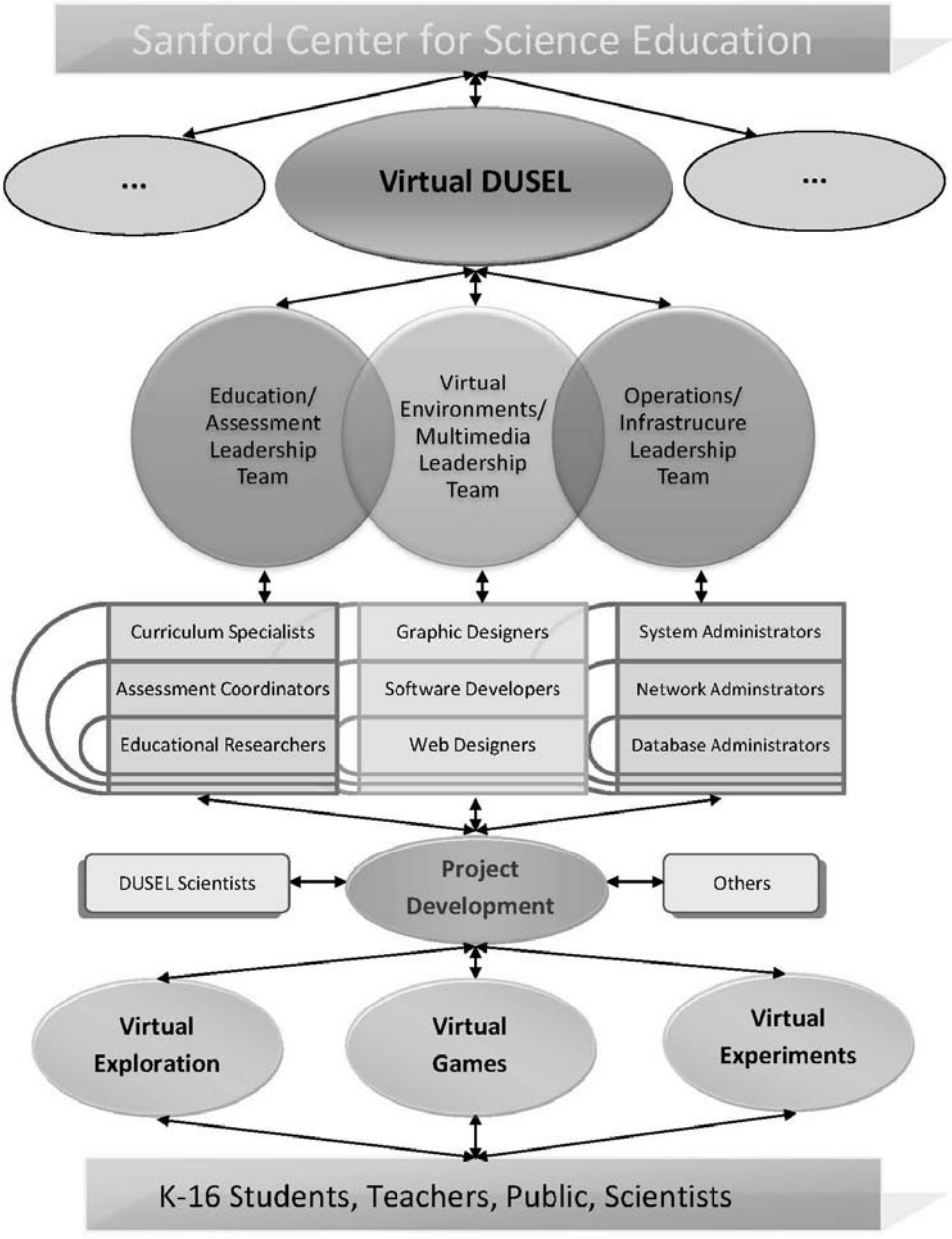

Figure 1: vDUSEL Structure

Early Focus – the CORE

Virtual DUSEL (vDUSEL) is the SCSE's online distance effort and has been tasked with developing innovative approaches for the delivery and support of E&O related to the Sanford Lab and DUSEL. To further this goal vDUSEL looks to develop a variety of immersive virtual environments that provide opportunities for virtual tours, virtual experiments based on actual scientific data, and immersive virtual games. A major early and necessary effort for vDUSEL is the creation of a stable, adaptable organization and technical architecture "CORE" in support of cyberinfrastructure-enabled learning and research projects related to DUSEL science. The technical architecture will combine virtual environment technology and an extensible framework for adding new content to meet the needs of both formal and informal education. The organizational architecture will bring together development teams from Dakota State University (DSU), South Dakota State University (SDSU), and other regional teams to effectively create and deploy this cyberinfrastructure-enabled environment.

The National Science Foundation's (NSF) Cyberinfrastructure Vision for the 21st Century [1], lays out several goals for learning about and with cyberinfrastructures that match well with the "CORE" development effort. The vDUSEL "CORE" development will:

- "foster a broad deployment of Cyberinfrastructure-enabled learning and research environments" by serving as a foundational piece of the overall vDUSEL effort to bring innovative approaches to E&O."

- "foster the development of new skills and professions needed for full realization of CI-enabled opportunities" by supporting the capacity building of the vDUSEL team members and undergraduate students in the digital arts & design, software development, and educational assessment of immersive virtual environments.

- "promote broad participation of underserved groups, communities, and institutions, both as creators and users of CI". The vDSUEL effort will increase research funding in the EPSCoR states of North Dakota and South Dakota. By developing an initial dynamic and extensible framework of CI technology, future efforts can be dedicated to supporting deployment in our rural and Native American populations.

- "stimulate new development and continual improvements of CI-enabled learning and research environments" The "CORE" architecture as part of the SCSE, will create a stable, long-term presence that will allow not only for a broad array of E&O projects across many sciences but also the ability to iteratively develop and assess learning models over time.

- "facilitate cyberinfrastructure-enabled lifelong learning opportunities ranging from the enhancement of public understanding of science to meeting the needs of the workforce seeking continuing professional development" The "CORE" will help support the development of projects allowing students to collaborate with other students at a distance, helping each other with science projects and motivating each other to learn. Interested members of the general public are able to stay informed about scientific progress at the mine. Scientists are able to disseminate their work to broader audiences to guide scientific inquiry. Mine safety training and mine engineering models can be developed.

Educational Issues

The implementation of educational games has many challenges including student access to technology, willingness of teachers to utilize games for learning, educational games perceived as purely entertainment, the need for more research to demonstrate the advantage of gaming over traditional learning, and cost. While a great deal of time and effort can be expended in the development of an educational game, there is no guarantee the game will be used in the school. There is the ever-present question, "If you build it, will they come?"

In the current K-12 environment of high-stakes testing, teachers are reluctant to use curriculum materials that are not grounded in solid research and directly aligned with state-mandated content standards. In the design of educational games and virtual experiments in the vDUSEL project, alignment with state and national curricula is critical. Beyond just the content, however, teachers, parents and administrators need to understand that educational games assist students in the development of other skills such as problem solving and cooperative learning.

The National Summit on Educational Games [2] was held on October 25, 2005 in Washington, DC. The Federation of American Scientists, the Entertainment Software Association, and the National Science Foundation sponsored the Summit. The Summit convened nearly 100 experts to discuss ways to accelerate the development, commercialization, and deployment of new generation games for learning.

- Many video games require players to master skills in demand by today's employers—strategic and analytical thinking, problem solving, planning and execution, decision-making, and adaptation to rapid change.
- They can be used to practice practical skills and important skills that are rarely used, to train for high-performance situations in a low-consequence-for-failure environment, and for team building.
- Games offer attributes important for learning—clear goals, lessons that can be practiced repeatedly until mastered, monitoring learner progress and adjusting instruction to learner level of mastery, closing the gap

between what is learned and its use, motivation that encourages time on task, personalization of learning, and infinite patience.

In “Creative Games for the Language Class,” Lee Su Kim [3] describes several positive aspects to the use of games in the classroom: games are a welcome break from the usual routine of the class; they are motivating and challenging; games help students to make and sustain the effort of learning; games provide language practice in the various skills—speaking, writing, listening and reading; they encourage students to interact and communicate; and, they create a meaningful context for language use.

Research in support of the value of educational games is also critical but much more elusive. While there is research evidence of the impact of educational games on student motivation there is scant evidence on the increased learning associated with them. "While educational games are commonplace, little is known about how, why or even if they are effective," said John Nordlinger, senior research manager for Microsoft Research's gaming efforts.[4] According to the National Summit on Educational Games

- Research is needed to determine which features of games and simulations are important for learning and why, and how best to design these systems to deliver positive learning outcomes.
- Research is needed to develop automated tools to streamline the process of developing games and simulations, and to reduce development costs.
- Research is needed on how to best assess the knowledge and skills learners acquire from games, and on understanding the barriers to the adoption of learning innovations in education institutions.

There is some evidence the impact of educational games may correlate to student performance level. Harvard University developed an education game called River City in which middle and high school students worked together to solve an epidemic. Early indications from research on this project indicate students with low grades did much better in the game than in other classroom projects. It is unclear why this correlation exists but increased student engagement likely plays a role. “However, mere enjoyment is not the only factor educators are now stressing. The major reason this immersive games are so vital to modern education is that they teach children problem solving skills. In scenario-based games, students have to connect several kinds of knowledge and experience to solve real-world type problems. This is a much more complete way of internalizing a concept, like taxation, than learning it in isolation.” [5]

Clearly educational research must parallel any game development within the vDUSEL project. Initial game design will be field tested and the results will inform changes in the game. This cycle will repeat itself several times before the game is ready for release to schools or the general public. Even if supportive research exists, since the term “game”

is associated with the development of these educational immersive virtual environments, parents, teachers and administrators will not necessarily buy into their value and this must be taken into consideration in the promotion of any educational game. While there are many challenges to the development of educational games, there are several examples of successful projects and the vDUSEL project will look to these past efforts for lessons learned and guideposts in development.

Implementation Issues

A key aspect of vDUSEL is that development of the virtual resources and environments will necessarily be distributed. And the distribution is a central consideration -- vDUSEL projects will not be large central teams with a few distributed members, but will be essentially distributed, with typically no more than one third of a project team co-located. This presents both a challenge and an opportunity for vDUSEL. While distributed development is not new, neither is it widespread. Supporting technologies exist but are relatively new with smaller installed bases. Communications and resource sharing provide fundamental challenges. Besides the challenges, the distributed development provides the opportunity for the design and development efforts to mirror the challenges of the audiences for virtual DUSEL. Such audiences are distributed, remote and often relatively isolated. Yet, for the vDUSEL efforts to be most effective, learning communities will have to be created which embed isolated participants into substantial, varied, and active virtual learning communities. As a result, the designers and developers of vDUSEL resources will need to function as an active virtual community. As new designers and developers become a part of vDUSEL projects, there is an explicit need for a learning community: they must learn about core vDUSEL resources, as well as about relevant aspects of DUSEL science and experiments.

Any distributed development effort has to rely on communication tools and resource repositories. While not mandating their use, vDUSEL projects will rely on online project management tools and repositories. A good example of such a system is trac. trac provides project management tools, such as web-pages, timelines, milestones, bug tracking and task allocation, and a version control repository. The web-pages within trac are managed as a wiki for team members, allowing collaborative creation of elaborate websites incorporating documentation and discussions of project design decisions, architectures, and elements. The wiki approach provides version control for the site pages, providing a history and the ability to perform and merge simultaneous work by team members. Sites such as Wikipedia demonstrate the capacity for the wiki model to support complex and effective distributed interactions.

The vDUSEL team has experimented with Microsoft Groove for use in virtual development. So long as the members of the project have Groove and are able to work in

a Windows environment, this can be an effective resource. However, the benefits of trac (or similar resources, for example Google Code) is that the requirements for effective collaboration are low: a functioning web browser. trac's services and utilities -- wiki, bug-tracking, milestones, source control, etc. -- are available to any user via their browser. trac makes no assumptions about the technology involved in the development effort, so any sort of resources can be used. However, trac makes no provisions for communicating among disparate tools a team might use for creation of project files. trac can share the Microsoft Word file created by one team member, so that a second team member can access it. But if the second team member is working under Linux, the capacity to view and edit the word file is a requirement of the team member's environment (e.g. OpenOffice) rather than a service provided by trac. This contrasts with the collaborative approach enabled by online tools such as Google Docs. While using strictly online tools facilitates collaboration and exchange of documents, there are at least two significant costs: performance of applications running over a network rather than a local machine; and the limited choices of applications which support such networked use.

For vDUSEL, the advantages in a broad range of choice and in performance outweighs the benefits of strictly online tools. Tools for the creation of virtual resources include modeling, graphics, and animation packages which can strain the resources of a development environment on a local machine. Availability and utility of such packages for networked use is limited. (Some can be used effectively over a LAN, but this isn't relevant for the widely distributed vDUSEL context). Among other factors, such tools are intricate and complex. Designers often become adept at the use of a particular tool or tool suite and productivity drops significantly when using a non-preferred platform. This implies that for an effective development effort, vDUSEL will have to support team members working with their tools of choice -- whatever those may happen to be. As a simple example, DSU 3D modelers are typically adept with 3ds Max, while at NDSU much of the modeling is done using Maya. Other modelers may use Blender or MilkShape or SketchUp or .... Besides designers using their tools of choice, there are tools which must be accommodated since they are part of a standard suite used for the Homestake Goldmine, and later, DUSEL engineering and management. Substantial models of the Homestake mine already exist of in Vulcan3d, Maptek's geological modelling and mine planning software. Engineers at LBL have done design work for DUSEL and its labs and facilities. This work has made use of the CoCreate package for 3d CAD modeling. So, besides, the geographical distribution of the vDUSEL efforts, there will be distribution across a variety of tools and formats for for the components, assets, and resources which will comprise vDUSEL environments.

The need for interchanging information among diverse modeling and design tools is well known, and many tools provide for export and import of components to and from other design packages. However, such exchange is often imperfect. Information can be lost. Model features don't map exactly onto each other. Successful exchange often relies on limitations on the size or scope of the models. Besides exchange among the design tools, the engine software which drives and manages virtual worlds or games using these

components often present their own restrictions. A significant part of vDUSEL will be developing processes to support the flow among these diverse tools and their end targets. This will include acquiring, installing and testing tools and utilities to perform conversions. In some cases, such utilities will need to be created. Testing will have to establish parameters and limitations which will affect exchanging assets among the tools. The results of these efforts will have to be collected, documented, and made readily available. Processes will have to be shaped so that designers become aware of conflicts and limits early in the development efforts. Additionally, since significant virtual worlds or games rely on extensive collections of both two and three-dimensional assets, the processes will have to be made efficient so that designers from diverse locations can develop their models, and transform them appropriately for downstream use. Since game design is a fundamentally iterative process, information and updated models will need to be able to flow in both directions. This suggests that encapsulating parts of the process and conversions within scripts or even GUI utilities may be the most effective ways to manage asset exchange. Some developers will necessarily be conversant with the full complexities of exchange among the various tools. However, most designers should be shielded from any complexity related to conversion among formats except for those aspects essential to the tool they use and the target tools which use their products.

While the distribution and diversity among the vDUSEL project teams creates challenges, it also guarantees a fundamental coherence. Just as project members have to face the consequence of their distributed and diverse development, users of the vDUSEL products will be geographically remote, as individuals or small groups, with diverse resources and equipment. The parallels suggest that vDUSEL development can be unusually sensitive and responsive to the demands of a distributed environment. Just as vDUSEL process and development activities have to extremely clear and well documented, end-users will value clarity and effective documentation. So that the empathy based on similar challenges can be even more effective in shaping the products of vDUSEL efforts, whenever possible, the same scripts, GUIs, interfaces, and metaphors will be employed in the development processes as in the end-user products.

As part of the vDUSEL effort, we will be establishing measures for the effects of distribution and diversity within and on the design and development effort. Besides measuring the essential diversity, we will also seek to measure the effectiveness of efforts to improve collaboration and flow. Both classes of measures will be adapted to (and from) measures for the audiences and effectiveness of vDUSEL end-products. Within vDUSEL the focus of these measures will be improvement of the processes, but we will also be looking for correlations between the project teams and project users. Our expectation is that similarities of the development context to the use context will lead to more effective products.

Conclusion

Virtual DUSEL (vDUSEL) is being developed as the online distance presence for the Sanford Center for Science Education (SCSE) which will serve as the Education and

Outreach (E&O) effort of the proposed Deep Underground Science and Engineering Laboratory (DUSEL) being developed at the former Homestake Mine in the Black Hills of South Dakota. Virtual DUSEL will be, in part, an organization of immersive virtual environments that allow visitors to experience the various aspects of the underground laboratory. Its development will require a collaborative effort of local, state, national, and international efforts.

A few themes distinguish the vDUSEL project:

- vDUSEL is focused on the "long haul" – building a collaborative virtual organization which will last for decades, rather than the duration of an individual project.
- vDUSEL is not a single project, but a range of projects exploring diverse aspects of outreach and education, and involving researchers in content areas with researchers and designers in education, software, and media.
- Expressing science and experiments in context is a vital part of effective outreach. This context includes the development and evolution of the lab and its experiments, along with the history, culture, and individuals associated with the lab.
- vDUSEL provides immersive virtual experiences for those unable to reach the lab, but also works closely with the Sanford Science Center to coordinate physical visits and virtual continuity, creating a learning community.
- Assessment is pervasive throughout vDUSEL, so that its elements can evolve, grow, and become more effective over time.
- Genuine science is fascinating – vDUSEL simulations, games, and virtual environments aim to capture the excitement and wonder of science – not pristine and plastic, but challenging and grubby and hard work – by asking, and providing the tools and data to answer, real questions.
    - An explicit goal of vDUSEL is to ignite viewers' interest in Science, Engineering, Technology and related fields.
- vDUSEL will serve a broad, varied, and changing audience, so it will be comprised of adaptive, interconnected components, rather than a monolithic structure.

The following are a few keys links related to vDUSEL DUSEL, the Sanford Underground Lab at Homestake, and Homestake Mine:

http://vdusel.dsu.edu/

http://www.lbl.gov/nsd/homestake/

http://sanfordlaboratoryathomestake.org/

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References

[1] *Cyberinfrastructure Vision for 21st Century Discovery*, NSF 07-28, National Science Foundation, March 2007.

[2] *Summit on Educational Games: Harnessing the Power of Video Games for Learning*. Federation of American Scientists. 2006. Washington DC. vww.fas.org/gamesummit/

[3] Kim, L. S. (1995, March). Creative Games for the Language Class. Forum, 33 (1), 35.

[4] DigitalMediaWire Daily, October 7, 2008 - http://www.dmwmedia.com/news/2008/10/07/microsoft,-universities-fund-research-educational-games

[5] Rebecca Hersh: "Video Games and Academic`s: New Ideas in Educational Gaming" - http://educationalissues.sthte101.com/article.cfm/video_games_and_academics