THE USE OF INFORMATION TECHNOLOGY TO ENHANCE LEARNING IN GEOLOGICAL FIELD TRIPS

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ABSTRACT

Two different approaches to enhance learning in geological field trips by the use of modern technology have been tested on a group of students from Norway on a field trip to SE Utah. The first was to use an advanced flight (field) simulator to help students obtain an overview and understanding of the study area prior to, during and after the field course. In a field simulator, the topography can be covered by several different attributes such as geologic maps, satellite images and aerial photographs in order to allow a comprehensive geological understanding that would be difficult to obtain by other means. In the other approach, the students were provided with digital camera and a portable PC. They worked in groups using problem-based learning methodology (PBL) and documented their acquired knowledge in a standard software presentation program. One of the benefits is that the results with pictures can be presented to the other students the following day. Based on the teachers' experience and feedback from the students, there is little doubt that the two approaches enhance learning. The field simulator facilitates a quicker and fuller geological understanding of a study area whereas the student presentations encourage reflection of the totality of what they have learned.

Keywords: e-learning, field simulators, Utah, problem-based learning, collaborative learning

INTRODUCTION

Recent advances in information technology (IT) change the way we work. Computers allow for documentation and analysis anywhere and anytime. Used in conjunction with a digital camera and/or a digital camcorder, it is possible to enhance the learning process associated with geological field trips.

Field trips are essential to allow for a fuller understanding of geological complexities. For example, they provide the student with a realistic understanding of spatial geometries of sedimentary and structural features, as well as petrophysical and diagenetic characteristics and processes. Furthermore, field trips represent some fundamental educational principles essential to enhance and support the learning efforts of those participating. Firstly, learning should be regarded a social activity (Bakhtin 1981). This fundamental principle is highly encouraged during field trips and is an important factor explaining why this form of learning activity is both popular and effective. Field trips also encourage the use of problem-based learning methodology (PBL; Hård af Segerstad 1999) by allowing students to work in groups solving specific problems. This strengthens the social activity and increase learning by group reflection and discussion. Secondly, learning is best done by "doing". This principle traces back to Dewey (1944), and has never lost its explanatory power and empirical penetration in real-life situations.

This paper discusses two different ways that IT and field trips can be combined to enhance learning. One is to utilize flight (field) simulators. The other is to document learning while in the field by using presentation software and a digital camera/camcorder. Field simulators can combine topography with any type of attribute such as geological maps, topographic maps and satellite images. The student-made presentations can incorporate multimedia and be interactive in order to stimulate the learning activity.

The present study is based on a structural geology field trip to the Colorado Plateau in southeast Utah (Figure 1) for graduate students from the University of Bergen, Norway. The Colorado Plateau provides insight into deformation geometries relevant for those observed in extensional settings, such as the North Sea rift between UK and Norway. The North Sea oil and gas reservoirs comprise mainly Jurassic and Triassic sandstones with high porosity and permeability, quite similar to those found on the Colorado Plateau (Fossen and Hesthammer 1998, Hesthammer 1999, Hesthammer and Fossen 2001). Since most of the geology students in Norway end up working for oil companies, it is important to introduce them to relevant problems related to the development and production of oil and gas. Readers should note that the purpose of the field trip to Utah is not to teach the students geological field techniques such as data collection, geological mapping and analysis. Nor is this a field course meant to introduce the students to basic sedimentology, petrology and structural geology. Instead, the target group is graduate students and the purpose is to enhance learning related to specific geological and geophysical problems relevant for oil and gas exploration and development offshore Norway. This

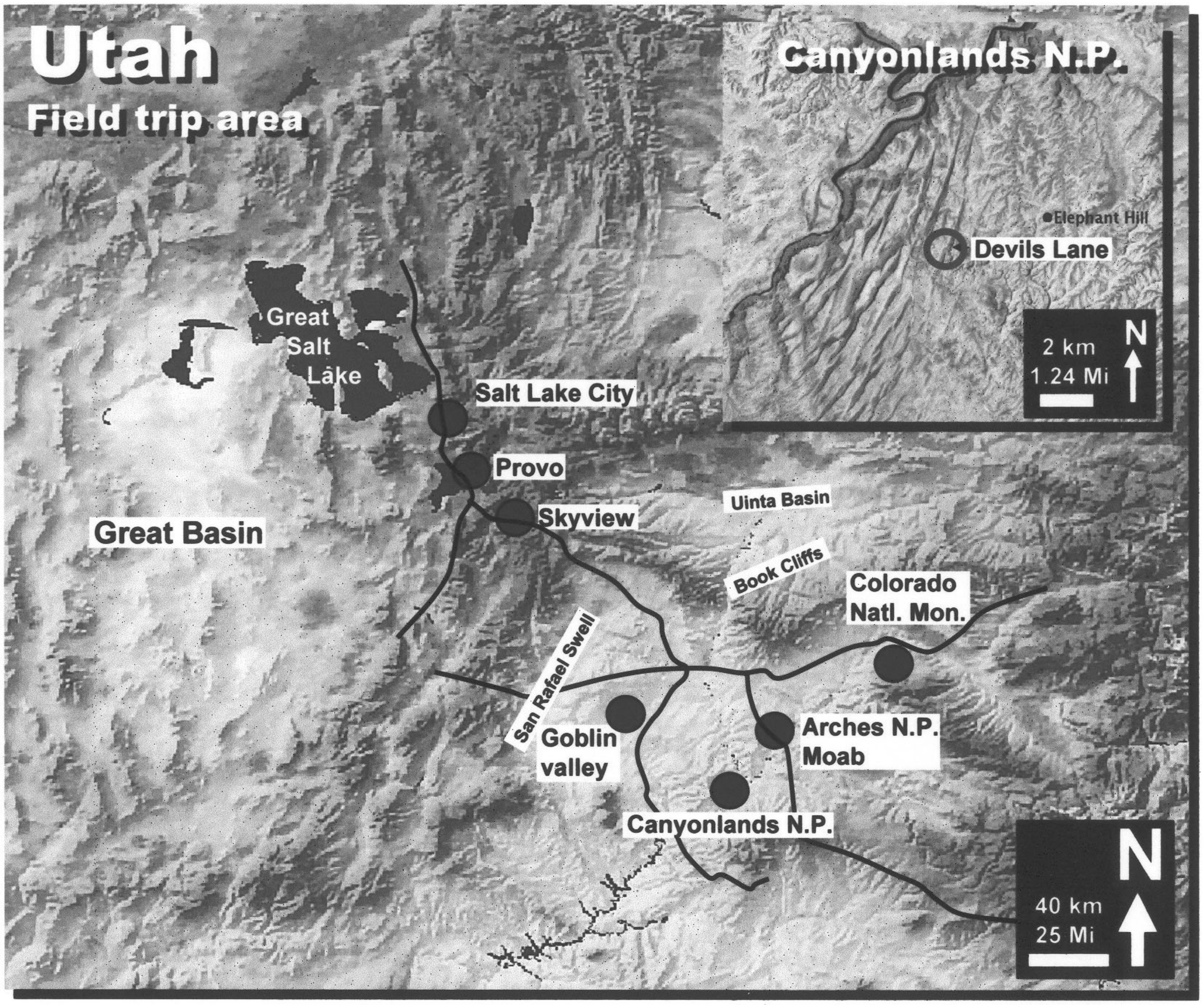

Figure 1: Location map showing satellite images from Utah and Canyonlands National Park. Circles indicate main field trip locations. The students used digital cameras to record important observations from all field locations. During the day, they worked in groups, discussing relevant problems. After arrival back in camp, one of the groups would be responsible for compiling the acquired knowledge into a digital presentation that would be presented to the other groups prior to next day's field trip.

includes knowledge related to topics such as seismic resolution, spatial and geometric fault characteristics, uncertainties related to fault sealing analysis, placement of wells and drainage strategies.

The field trip to southeast Utah is a part of a joint venture between the Norwegian oil companies and the Norwegian universities (Hesthammer et al. 2001a). The project's goal is to help modernize petroleum geoscience-related learning by utilizing problem-based learning and information technology. In particular, data from the Gullfaks Field, northern North Sea (Tollefsen et al. 1994, Fossen and Hesthammer 1998) have been made available to the Norwegian universities so that academia can introduce real data and real problems into student learning activities. This motivates students both because they see the relevance of the knowledge they acquire and because of the contact they establish with industry employees (Fossen et al. 2001).

PART I: ENHANCED LEARNING BY THE USE OF FIELD SIMULATORS

The concept- Students in the field learn by observing geological features and understanding the significance of the distribution of geological units and structures. An important aspect of the learning is to obtain an overview of the area and relate this to the details observed. There are some clear limitations associated with this. For instance, students walking on the ground will have problems obtaining an overview of larger-scale

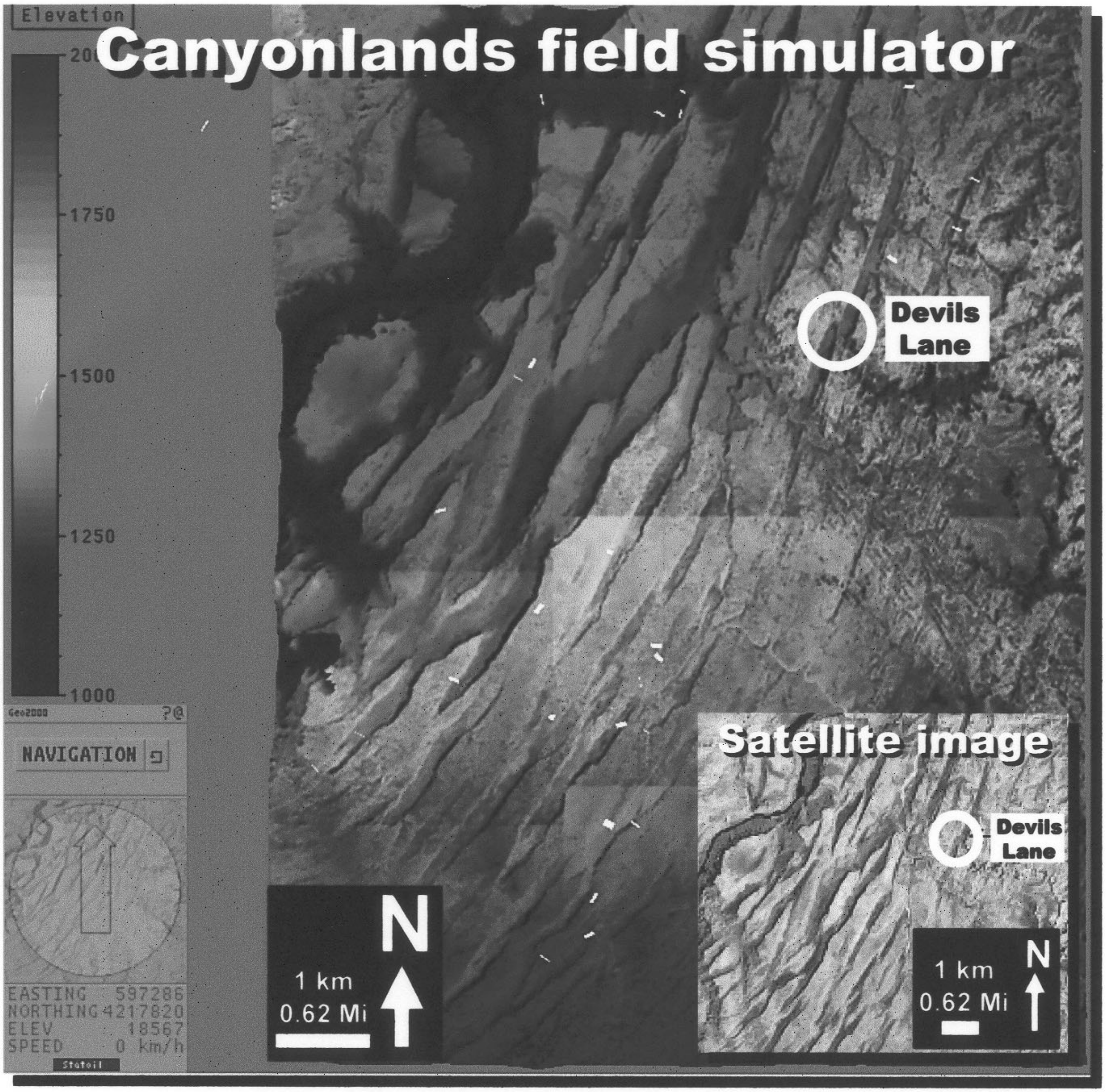

Figure 2: Overview of the Canyonlands National Park area covered by the flight (field) simulator. The white circle indicates the SOB Hill location in Devils Lane. The color changes represent variations in elevation. Blue color indicates deeper elevations and red color shows higher elevations. The scale bar to the left shows elevation in meters above sea level. The lowermost left part of the figure shows the navigator which is used to show attributes such as location, direction, elevation and flight speed. In addition, the navigator gives access to different textures such as satellite images and aerial photographs as well as way-points that enables the user to quickly access an area of interest. Also, the user can, within the navigator, turn on or off information such as pictures, geological profiles and slide presentations. There are two different flight operation modes and the user controls the flight using the mouse and keyboard. The navigation is similar to that of other commercial flight simulators and the user can freely move around in the area and change speed, orientation and flight direction. The inset map shows a satellite image from the same area.

structures such as large fault trends, folds and lateral changes in sequence stratigraphy. They may not be very familiar with geological maps and thus the understanding of the relationship between geology and topography. To learn geological mapping is time consuming and many universities arrange undergraduate field trips with this as the main learning goal. Also, there are limitations related to mobility. Walking is slow, driving usually restricted and parts of the field area may even be inaccessible due to rough terrain or property restrictions.

A helicopter provides both overview and mobility, but is too expensive (if at all accessible) for most field trips. In addition, the use of a helicopter does not necessarily provide an insight to the geology of an area. Information technology provides new means for simulating helicopter rides in the form of flight simulators (referred to as field simulators in this study). Such simulators are already familiar to many students in the form computer games. One of the main challenges has been to implement larger areas with sufficient detail into PC-based simulators. However, the latest portable computers have enough power and capacity to run very detailed (1 m resolution) simulations of reasonably large areas with sufficient response time.

The benefits of incorporating field simulators into geological field trips are many. First is that of visualization. Topographic and geologic maps may be hard to understand for those not highly familiar with them. A field simulator allows for "3D" visualization of the topography. It is also quite possible to provide real 3D experience by the use of polarizing glasses (this applies to the Canyonlands field simulator described in this paper), although this may be difficult to implement in field.

Field simulators also help the student to understand the relationship between topography and geology. As such, the simulator provides insight into intricate problems such as how a dipping geological layer appears on a map across a river. Also, other spatial relationships between stratigraphy and structural geology (folds and faults) are easily visualized. Furthermore, the field simulator does not have any restrictions on mobility and the student can move freely around the study area.

A helicopter ride restricts the surface attributes to vegetation, rocks and sediments. Although a field simulator is very different from a helicopter ride, it gives the user full access of mobility with respect to speed, direction and elevation similar to a helicopter ride. In addition, the surface attribute can be anything such as satellite photographs, geological maps, topographic maps or aerial photographs. Combining these different attributes helps the students to get a comprehensive understanding of the area.

THE CANYONLANDS FIELD SIMULATOR

Before the field trip, we wanted a field simulator to be used for study of large-scale structures and detailed geologic features. When running the simulator it should be easy to compare the modern terrain with paleo-terrains mapped from seismic data. The terrain should be able to show variations in elevation as color variations. In this way it should be easy to compare the actual surface terrain with relevant mapped subsurface terrains. Furthermore, it should be easy to project other types of data such as pictures, text and geomodels onto the terrain model. The software should enable interaction such as controlling the "helicopter" and making measurements within the model. It should also be possible to make geological sketches of outcrops when running the software.

To achieve these goals, the simulator was designed for a geographical area covering 10 x 12.5 kilometers divided into 2000 times 2500 grid cells. The ground resolution in the model is thus 5 x 5 meters. In order to be able to operate such a large amount of data on a portable PC, it is necessary to perform some sort of data reduction. In the current field simulator, this is done by a continuous and detailed real-time rendering of the field data. This methodology works well on portable PC's containing disks with high search and data transfer rates. The error tolerance can be adjusted while using the software program.

The navigation system is similar to that of commercial flight simulator software programs (e.g. Microsoft® Flight Simulator) and only a standard three-button mouse is needed. However, the system also supports more advanced equipment such as "joy stick" and "space ball". The user can adjust flight speed, direction and elevation by using the mouse and keyboard. The navigation system is similar to that of pocket GPS's and allows the user to constantly keep track of all parameters. Also, the use of way points allows quick transfer to sites of interest.

There are two texture types available for the Canyonlands field simulator. One is an elevation-colored texture (Figure 2 and Figure 3) whereas the other is a panchromatic ortho-photo with 0.8 meters resolution. When including a large area with high resolution into the ield simulator, the student can perform regional (Figure 2 and Figure 3) and detailed (Figure 4) studies on the same data set. Other data types than terrain and texture can also be imported as VRML ("virtual reality modeling software") or similar formats. This enables the user to include measurements or simulations while working within the system. This may be magnetic data, gravity data, geological profiles, maps and interpreted seismic lines. To enable very detailed studies we have also included digital images captured from helicopter or from the ground (Figure 3). In order for the simulator to work efficiently, it is necessary to reduce complexity and amount of virtual data to a minimum. To obtain this, the Canyonlands field simulator uses the software "Rational reducer" from Systems In Motion (Norwegian software company;).

In addition to the Canyonlands field simulator, the concept has been used with success for a number of other

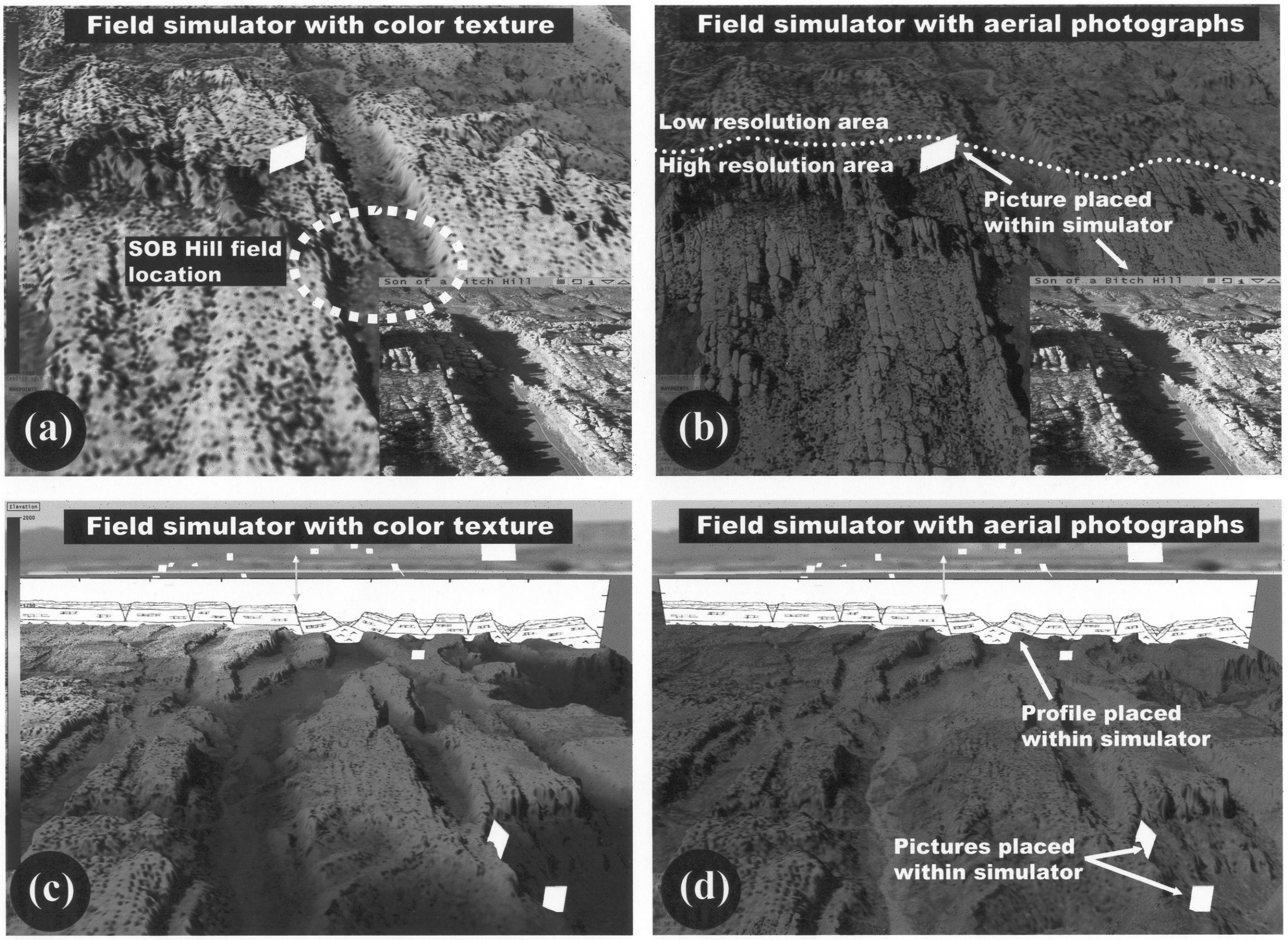

Figure 3: (a) Flight (field) simulator capture of the Devils Lane area and the SOB Hill field location. The elevation changes are color-coded with green representing the deeper areas and yellow and red representing higher elevations. The ground resolution is 5 x 5 m. A photograph taken from helicopter is shown in the lower right corner of the figure. This picture is placed within the simulator and the user will see the content of the picture when within a certain distance. By clicking on the picture, the user is automatically brought to a viewing position that enables him or her to compare a real photograph with the digital field simulator view. Also, by clicking on the status bar within the picture, the user can access information such as a description of the area and geological interpretation. (b) Same as (a) but with aerial photographs draped onto the topography. The resolution of the photographs is 0.8 m. This provides the user with much more details than by the use of color-coded texture. Fracture systems and roads are easily observed using this texture. (c) Field simulator capture from a different part of Canyonlands National Park. The deep blue color in the upper right corner shows the location of the Colorado River. A geological profile is placed within the simulator and the user can drag the profile vertically using the mouse. The white areas are photographs placed within the field simulator. (d) Same as (c) but with aerial photographs draped onto the topography.

areas such as Spitsbergen (Norway), Lofoten (Norway) and South Africa. The cost of developing a field simulator for PC, provided that terrain data are available, is relatively low (less than a few tens of thousand dollars). However, depending on the amount of wanted extra functionality and data such as profiles, surface attributes and measurements, the cost quickly increases. The field simulators, which are developed by Statoil (Norwegian oil company;) and System In Motion, has been installed on all Norwegian universities at no cost for educational purposes. This allows students and faculty to enter data themselves, thus significantly reducing the cost of developing an advanced field simulator. For more detail discussion on the design and implementation of computer-based terrain models in geological training see Sæther et al. (in review).

IMPLEMENTING A FIELD SIMULATOR INTO THE FIELD TRIP

Field simulators can be used before, during and after the actual field trip. In the present study, the students where introduced to the simulator in the morning before visiting the field area. The study area contains relay structures in a horst and graben system located within Canyonlands National Park, southeast Utah (Trudgill and Cartwright 1994, Moore and Schultz 2000). The area is relevant for problems related to fault sealing in the North Sea reservoirs. Many of the structures are on a subseismic scale and thus not possible to study in detail from seismic data. In the Canyonlands National Park, the degree of exposure is excellent and the area provides some of the best examples of relay structures in the world.

The exercise started by showing the study area at high altitude to give the necessary overview (Figure 2 and 3a-b), followed by an interactive "flight" into the area that the students would walk by foot later in the day (SOB Hill and Devil's Lane in Canyonlands National Park, Figure 4a-b). The next part of the session focused on areas that the students would not visit, in order to demonstrate that there are many more examples of relay structures that the students would not have time to see in the field. During the flight, the students could see pictures from the area that had been incorporated into the simulator (Figure 3). Finally, the session ended with a flight back to high altitude in order to see the detailed structures in a larger context.

The students stayed in a motel, and the field simulator was displayed on a wall in one of the rooms using a portable video projector. The software was installed on a powerful portable PC capable of handling the computations and large amount of data.

After the field trip, the field simulator was installed in a project room at the University of Bergen, Norway. This was done to give the students the opportunity to try the simulator at their own convenience in order to further enhance their learning experience. Also, the installation at the university facilitates the use of 3D technology (by the use of polarizing glasses).

EVALUATION OF THE FIELD SIMULATOR

In order to do a proper evaluation of the use of the flight simulator and the other information technology (IT) learning devices, and also of the learning outcomes of the field trip as such (part II of this article), we conducted a semi-structured group-interview (Kvale 1989) with some of the participants from the trip. The interview allowed for both individual and group reflection and elaboration.

The main focus in the interview was how the participants experienced the use of IT as an integrated part of the field trip. More specifically we were interested in how the use of IT supported and enhanced their collaborative learning efforts, and to what extent the participants experienced IT as a means to support documentation, description, reflection and understanding.

Learning geology is in many cases a form of learning by formal representations. Maps, sketches and models are all formal representations in 2D representing 3D realities and even the 4D stories of how the geological events led to the resulting formations. Ideas of sedimentation, folding, faulting and erosion are not always difficult, but the formal representation of all that information in one 2D diagram is difficult, and needs special care in its presentation (Laurillard 1997).

By using a field simulator, in this case a modified flight simulator, one can overcome some of these difficulties, and even have the additional benefits of interaction and freedom of movement in the represented reality.

The students particularly focused on this issue in the interview:

"It was very useful to get an overview of the area before we started our walk into it."

"The field simulator made geologic forms which otherwise had been more difficult to gain a geometrical understanding of, more accessible and more understandable."

"The field simulator was very useful to get the big picture. And if you missed something you could just "fly" back and see it again."

After returning home from the field trip, the flight simulator was installed in a project room at the University. Although none of the students had tried it out prior to the interview (due to practical reasons), they indicated that this would certainly add to the learning from the field trip itself:

"Trying out the field simulator after returning home would probably make many "bits and pieces" fall into place."

"After studying relay ramps in detail by walking in the area, it would be very nice to be able to "fly" through it at different altitudes to see the big formations and structures."

However, the students also clearly stated that, by their opinion, the use of a field simulator could never replace the learning effect of the field excursion. When challenged on this, they explained:

"First of all the simulators of today are far too superficial. You don't get the detailed view you need to really understand all aspects of geological structures."

"There is also the matter of becoming familiar with the area by walking into it, taking your time to reflect and discuss. Standing in the middle of the formations with the wind in your face and the sounds from the nature can't be replaced by a field simulator."

But having said this, they were again very quick to emphasize that the use of field simulators represents what they called "an enormous leap forward from the 2D maps and sketches."

As a conclusion we can say that the students, despite the limitations in today's technology, clearly found the flight (field) simulator useful. As a formal representation it has clear advantages compared to 2D representations. The possibility of interaction, to choose where to go, when to go and what to see is considered a gem among the IT available for learning geology today.

PART II: DOCUMENTING LEARNING DURING THE FIELD TRIP

The concept - Traditionally, students document what they learn in the field by using a field book in which they write necessary text and data. They may also take photographs. At home they develop the film and write up a report. The introduction of new technology provides possibilities for valuable "add-ons" to the standard documentation method. The use of a digital camera, camcorder and a portable computer allows for report writing while in the field and, at the same time, helps the students to reflect upon the acquired learning at the end of the day.

With a digital camera, students can take pictures during the day and temporarily document their observations in a field book. Towards the end of the day, they can select the pictures that they want to use for their final presentation. Back in camp, they can quickly import the pictures into a software presentation and add necessary text on a portable computer. They may further process the file at home in order to provide a field trip report as a joint effort between all the students rather than creating many individual reports. Commonly, focus in academia is on the delivery of individual work. In the industry, on the other hand, focus is on project work with several participants. It is the authors' opinion that both aspects must be addressed and learned by the students.

IMPLEMENTATION

Twenty people, including fourteen graduate- students, four PhD-students, one post-doc and one company employee participated in the field trip. One university employee and one company employee guided them. The students were divided into five groups, one for each of the field days.

In the field guidebook, several questions helped the students approach each task using problem-based learning (PBL). The group responsible for documenting the specific day's content, collaborated in order to select relevant digital photographs and to answer the questions in the field guide. The pictures were downloaded onto a portable computer and imported into a Microsoft® PowerPoint presentation.

The template for the presentation was created in advance of the field trip. It contains a title page with a picture of the student group, name of the participants and a relevant title for the day's theme. Following this are session pages that allow the students to give an overview of each session. Each of these pages is linked to another page that contains only the figure enlarged to cover the whole page (see also Hesthammer et al. 2001b, c). As such, the setup is simple and easy to understand even if the students do not have previous experience with Microsoft® PowerPoint. The final page summarizes the main points.

Due to tight time constraints, the presentations do not utilize advanced functions such as animations or sound. Generally, the students arrived at the motel at sunset. The group responsible for documentation could choose to create the presentation before or after dinner. Whatever they chose, the presentation could not take longer than approximately two hours to finish. This put the students under significant stress and it was absolutely necessary to complete most of the storyboard for the presentation while in the field.

The following morning, the students gave a presentation of their work from the day before. This was carried out in one of the motel rooms using a projector and a portable PC. The presentation lasted approximately 15 minutes. After the field trip, it is possible to enhance each individual presentation and combine them into a single report that is a joint effort between each participant and each group.

EVALUATION OF THE DOCUMENTATION METHOD

The first group was only briefly explained the concept. They were told to take approximately 10 pictures with a digital camera and relate these to the problems defined in the field guide. They did not in advance see the Microsoft® PowerPoint templates that they were to document their work in. Furthermore, they were not specifically told to focus on the development of a storyboard during the day. They arrived late at the motel and did not finish their work until midnight. The presentation consisted of four pages in addition to the introduction and conclusions. Their documentation was brief, but contained the most important elements.

In spite of great enthusiasm within the group, there were some obvious problems related to the group work. The members of the group had not worked together prior to the field trip. They were not familiar with the PBL methodology. Furthermore, they were uncertain about how to approach the task with respect to what to include and how to build the sentences to be used in the presentation. As a result, the first page took almost half of the available time to create. The session had many similarities to team building sessions in that they were subjected to time constraints and the group members were tired while introduced to new topics and problems.

There were some clear lessons to be learned from the first group's work. First, it is necessary to focus more on group work during the day. Also, the group must learn to collaborate while in the field rather than in front of the

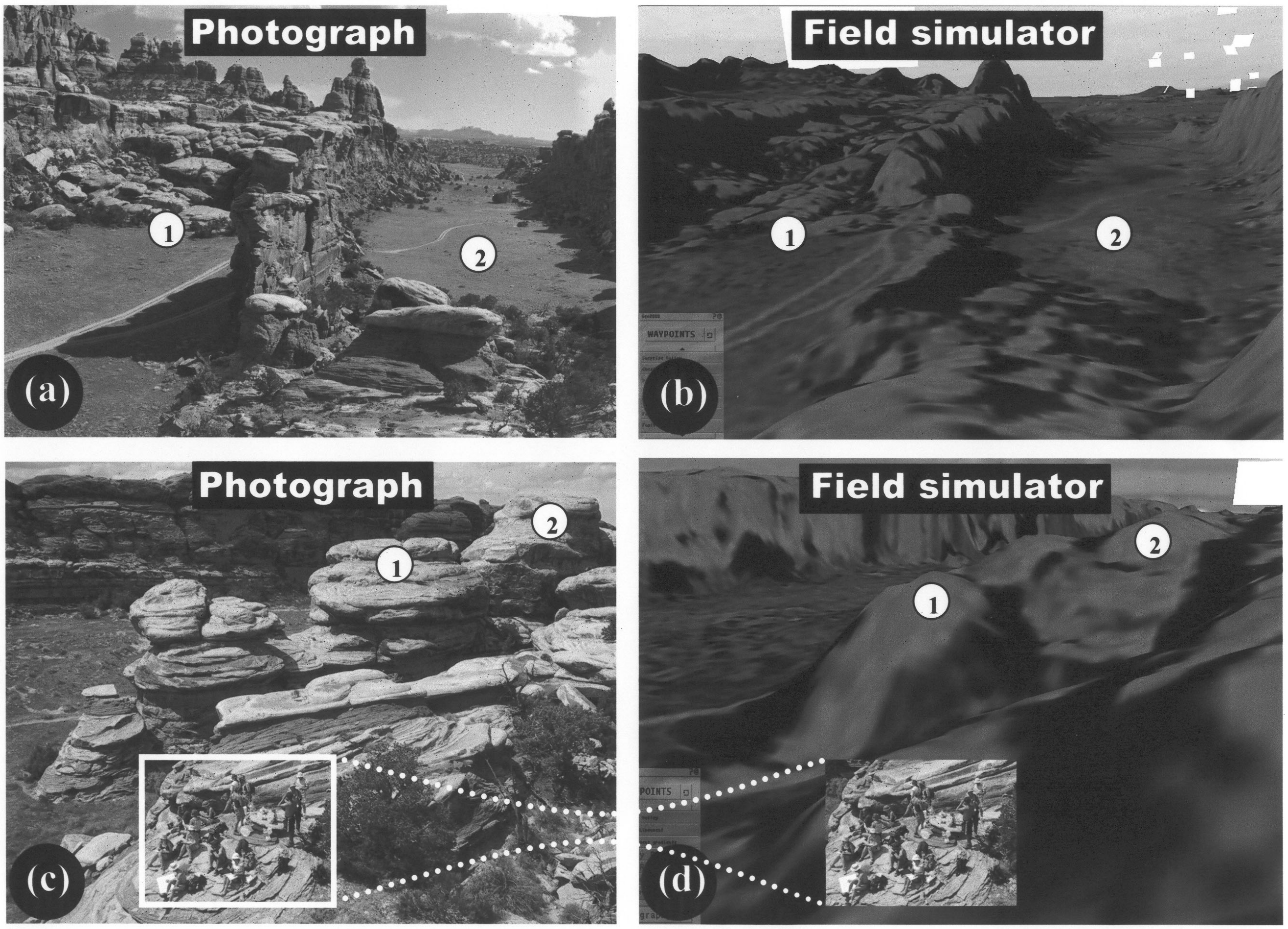

Figure 4: (a) Photograph of the SOB Hill area in Devils Lane. The area shows a relay structure where faults overlap but do not meet. Relay ramps form between the faults and the faults are characterized by rapid changes in displacement. The cumulative displacement of the overlapping faults remains constant. In seismic data from the oil and gas fields offshore Norway, the distance between the faults would be on a subseismic scale. As a result, the faults would be mapped as a single continuous fault surface. This information would subsequently be used as input to software calculating the sealing capacity of the fault. Obviously, the existence of a relay structure may render such analysis useless, and this is the one of the main points of interest at this location. (b) Field simulator capture of approximately the same area as shown in (a). Due to limits in resolution, the field simulator cannot compete to the resolution of normal photographs at this scale and this clearly demonstrates one of the reasons why it is still important to bring the students out in the field. However, the field simulator allows the student to rapidly move around to other locations, something that is not easily done while in the field. In fact, the students can only spend 1-2 hours (including lunch) at the SOB Hill location in order to reach back to the cars before sunset. (c) Photograph from the entrance to Devils Lane. (d) Field simulator capture of approximately the same area as shown in (c). Again, due to limits in resolution, the field simulator cannot compete to the resolution of normal photographs at this scale.

computer. Furthermore, they need to agree on the storyboard while in the field, including key pictures to be used and the associated text.

After the group had presented their work the following morning, the students discussed in plenum how the next group could benefit from the experiences. Ideally, this should help the next group to avoid doing the same mistakes as the first group. However, the second group made the same mistakes in that they did not clearly develop a storyboard and pick out the relevant pictures. They also ended up spending half the time on the first slide, significantly affecting the results of the following slides in the presentation.

Group three was specifically told to limit the amount of pictures and to develop the storyboard prior to arriving at the motel. The result was a more focused group that had most of the content ready by the end of the field day. However, the group decided to try to implement small animations. Such work is time consuming and the content of the presentation suffered from the exaggerated focus on presentation style. It is clear that such advanced use of the software should wait until after the field trip.

As explained, we used pre-fabricated templates in Microsoft® PowerPoint. During the interview the students reported the following on this matter:

"It was very useful to have the templates in Microsoft® PowerPoint. They saved us a great deal of time. The idea to use a projector on the wall worked very well."

"I haven't really learned how to use the software, but with the templates I had no problems writing down our findings and interpretations. Actually I would have liked to have more training in using Microsoft® PowerPoint as I am sure I will use it later, in my job."

No one reported any real problems using the Microsoft® PowerPoint template or the digital camera. As a result the same system with minor changes in the templates will be used in next year's trip.

Group four had the advantage of seeing three previous presentations and listening to the previous groups suggestions on how to develop the modules. This resulted in a better presentation both in content and with respect to presentation style. Still, the group did not manage to prepare sufficiently in the field to avoid the problems that the previous groups had experienced.

Group five had the advantage of knowing all the pitfalls that the previous groups had experienced. In addition, the last night was spent out in the field rather than in a motel. As a result, computer battery time restricted the total time available. The group was therefore forced to be focused and managed to finish their work in less than two hours.

The field guide, together with preparatory work like reading relevant articles and being presented with specific geological information about southeast Utah, provided the students with concrete problems to work on while in the field. One student comments:

"What distinguished this field trip from many others are the very clearly formulated questions and problems we were supposed to work on. This added direction, problem-oriented reflection, and focus on delivering "a product," to our work. The field guide was very helpful in this respect."

Also, it is clear from the pilot project that, although told, the students cannot learn to develop a good storyboard until they have tried and failed at least once. It would also probably work better to pick a person from each group to be in charge of the group work and to make sure that the group worked sufficiently together during the day.

When asked to comment on the group work in itself and the social processes, they said:

"When we were in the field, we mainly stuck to our groups. We discussed the different phenomena, reflected on how they came about, and prepared for the presentation."

"It was very time-consuming to work together on the presentation. In some cases it actually came down to how we should formulate the sentences with respect to grammatical issues. Weird! But this only shows that the group work back at university isn't really group work. We normally just split the parts of the assignments between us, and meet up when we have finished. This was different!"

"And then there was the time factor. We worked under considerable time-pressure to have the presentation finished within the time limit. I guess this is how it will be working as a geologist in the industry."

Besides learning a lot of geology, these statements from the students tell us some stories about meta-learning, and how the pros and cons of different learning strategies very soon became a precarious issue to solve. Subsequently the tension between surface and deep level processing and learning (Marton and Säljö 1997, Gibbs 1992) required that students with different kinds of learning strategies adjusted to other members of the group.

DISCUSSION AND CONCLUSION

Our experiences from this pilot project are very positive. Students were highly motivated to use modern technology to enhance their learning experience. The focus on group-work methodology and geologic relevance were other important motivating factors. Students are introduced to relevant problems, work routines and modern technology similar to that used in the industry, and they interact with industry employees.

It is of course possible to improve the concept by allowing more preparation both among the leaders and the students. The leaders need to focus on defining the problems and preparing the group for the task they are to undertake. In order to save time while in the field, the students will benefit by practicing PBL group work and to document learning in the same software programs that they will use in the field prior to the field trip. They should also use the field simulator in advance in order to become familiar with the field area.

Some IT-enthusiasts may argue that a field simulator has the potential to eliminate the need for field trips. Although impressed by the possibilities in the new technologies, we strongly advocate against this. Currently, the existing technology does not allow for imaging the details that can be observed in the field. Although the projected aerial photographs have a resolution of 1m, the resolution of the digital elevation model is considerably lower (5 x 5 m grid cells). As observed in Figure 4, there are many details that cannot be observed from the field simulator. For instance, the field simulator is not capable of letting students correlate the stratigraphy across the relay structures as seen in Figure 4a-b. However, the rapid technological advances will continue to close the gap between the digital world and the real world and it will be increasingly easier to apply IT during field trips to help enhance learning. As their usage gets more common, flight simulators and other tools may be exchanged between universities or available through the Internet and a new and exciting window of opportunities to enhance field-based learning will be opened. Another important aspect is that of reflection. Students in the field spend a lot of time together reflecting on their observations. It is important to allow enough time to process the many impressions. This is more difficult in an on-campus setting where there is pressure to attend other courses, prepare for exams and participate in a number of competing activities.

Those skeptical to the use of IT in field trips may argue that a series of good photographs, maps and satellite images for introducing students to a region works just as well as a field simulator. This is not our experience. One of the great benefits over photographs, maps and satellite images is the ability to move rapidly around in the field simulator and obtain perspective views from any elevation, in any direction and at any location. In addition, information such as maps, photographs, presentations, animations and videos can be placed at relevant locations within the simulator, providing easy access to such information.

On a more fundamental basis, the skeptics may argue that the concept of using IT in the field is in itself counter-productive and will do little to enhance student learning. The basis for such arguments may be that field time is better spent looking at rocks and working out the three-dimensional aspects with maps and aerial photographs. This is a relevant objection that the users of modern technology must consider. However, spending time in field and using modern technology may not be in contradiction to each other. Instead, the use of a field simulator can and probably should be restricted to after the students are back in base camp. Similarly, downloading digital images from a camera to a PC is also best done when back in camp. Furthermore, the teacher should be very clear on the learning goals when considering use of modern technology. If the main learning goal is to create a geological map from field observations, it may be better for the students to be introduced to the flight simulator towards the end of the field course in order to allow for a natural mapping progress. At this stage, scanned versions of the students' maps can be draped over the topography within the field simulator in order to provide effective evaluation and comparison of the results. The students would likely find this very stimulating and entertaining. With respect to the field trip to Utah for graduate students, the learning goals were not related to mapping procedures or basic understanding of structural geology as this was required prerequisites. Instead, the focus was on acquiring knowledge related to specific problems relevant for the oil and gas industry offshore Norway. The use of a field simulator ensured that the students quickly understood the general geology of the area as well details from sites that they could not visit. Also, the use of presentation software enforced reflection of the acquired knowledge related to specific problems. Based on the field leaders experience and the students' motivation and positive feedback, there can be little doubt that the use of IT on the geological field trip to Utah significantly enhanced student learning.

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