Modern field courses and problem-based learning; a comparison between industry and academia

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Abstract

Problem-based learning (PBL) can provide an attractive learning situation in relation to field courses. Combined with information technology, the learning effect can be enhanced compared with more traditional courses that use lecture-based learning and no advanced technological aids. However, the use of information technology in field courses requires the consideration of fundamental pedagogic principles. In May 2003, two separate geological field courses were run at locations in Utah and Colorado, one for students and the other for industry employees. Both students and industry employees participated in a pre-field course before going into the field. In the field the participants worked in groups, solving both general and location-specific problems. Several geosimulators (advanced flight simulators) based on digital terrain models for Utah and Colorado were used both prior to and during the field course. Satellite images, photographs and maps where incorporated into the models in order to provide students and industry employees with a complex technological learning environment. Also, the courses made extensive use of interactive multimedia learning modules that could be accessed both before and after the field course. A specially designed learning management system was used for the administration of the field courses. The highly positive feedback from both students and industry employees documents the effectiveness of the course form and use of information technology in conjunction with field work.

Keywords: IT-based learning, field simulator, flight simulator, learning modules, Utah, field work

Introduction

Extracting information from outcrop geology is essential to understand geological processes, consequently field work and field courses have been a traditional part of university courses in the geosciences. Due to the oil industry's increasing focus on computer technology, however, expensive and logistically demanding field studies have become harder to justify, but even more critical. As the portion of field work in university courses is reduced, a danger exists that basic geological understanding is weakened. After students graduate and begin to work, further training is typically "on the job" with even less time for field courses than before. As a result it is vital that all field courses are made as effective as possible.

This paper describes how the pedagogic concept of problem-based learning can be combined with modern technology in order to provide a more efficient learning environment. During May 2003, two field courses related to structural geology and sequence stratigraphy were run in the areas of southeastern Utah and eastern Colorado. One of the courses was held for university geoscience students at M.Sc. level, whereas the other course consisted of industry employees from a Norwegian oil company (working with problems related to one of the gas fields in the northern North Sea).

Both courses consisted of a pre-field course and the field course itself. During the course, participants worked in groups, solving relevant problems either related to the topics of structural geology and sequence stratigraphy or other problems relevant for the oil industry.

In relation to both the pre-field work and the field course itself, the participants used geosimulators (advanced flight simulators) and e-learning modules (interactive, multimedia learning experiences) to acquire necessary knowledge. The university students would also work in groups to create presentations that were given to other groups in the morning before entering the specific field locations.

Both courses were evaluated after finishing the field work. This paper uses this evaluation to argue that the combination of problem-based learning and information technology can provide efficient learning for participants in field courses.

Traditional field-based learning in geosciences

As described by Sæther et al. (in print), from which the following excerpts are taken, geoscientists must understand processes on a wide range of scales, from micro-scale mineral reactions to regional basin evolution, and how geological resources can be identified and exploited commercially. Traditionally, geoscience education has been a combination of classroom-, lab- and field-based learning.

Field-based learning for both students and professionals is usually done in the form of field courses or field work. Field courses typically involve a detailed program lasting one or more weeks and focus on a number of localities. Activities at each locality involve a combination of self-study, discussions, short lectures or lengthy explanations, depending on the course level and the preferences of the lecturer.

Field courses are a demanding mental exercise, combining visual observations and theory to understand complex processes. Learning in the field involves hard work and requires sufficient time for students to digest different observations at widely different localities. Preparation is crucial and course manuals and field guides are (or should be) supplied in advance to allow the students to prepare for the exercises they will go through in the field. Though students from both universities and industry typically don't use enough time for preparation prior to a course, this is normally not taken into account by the lecturer and may result in a stressed and inefficient learning situation. Field students often have problems knowing where they are in the general geological context and find it difficult to integrate local observations into a large-scale context.

Field-based learning allows geoscientists to select which localities they want to focus on and how much time they spend studying different topics or outcrops. Though student field work is usually guided by a supervisor, it usually involves a degree of freedom of thought, creativity and originality. Workdays in the field tend to be long and can include mapping exercises, detailed description of localities involving measurements, sampling, taking notes, making sketches, taking photographs, and making videos. University students normally present field work results in the form of a written report after the course, while professionals commonly have no requirements for writing reports. Field course reports can be quite extensive, and are often included as parts of university degrees.

Use of information technology in field-based learning

Sæther et al. (in print) correctly states that information technology (IT) have been used the last decade to visualize and analyze geological data both in industry and at universities. Topographic maps, air photographs and geological maps have become more available by means of standard computer software. New IT tools have been implemented to simplify work processes and improve interpretation capabilities. Good examples are 2D and 3D interpretation tools for seismic data and computer programs for advanced visualization of 3D data and integration of very large data sets, first developed by the petroleum industry. Also 3D visualization has become common practice involving the use of anything from small computers to large visualization studios.

New IT-based tools and work methods have permanently changed everyday life for geoscientists in the oil industry. Most problems are approached with the help of IT, which is also reflected in the teaching of geoscience subjects (Hesthammer et al. 2001 a, b). The term electronic learning (e-learning) describes learning activities aided by computer technology. Reading a textbook made available on the Intranet or Internet is the simplest form of e-learning. Computer "games" specially designed for teaching a particular subject such as seismic interpretation are technically a very advanced form of e-learning. An enormous variety of applications using IT to improve learning has been developed the last years in the Earth sciences (see e.g. www.dlse.org).

Digital terrain models

The idea behind a geosimulator (advanced flight simulator used for geoscience-related studies) is to establish a tool which makes it possible to do "realistic" field training on a computer, as an aid before, during and after the actual field activities take place. Although there are numerous programs for 3D view, e.g. GIS systems, no software packages aimed at applying digital terrain models (DTM) in field-based learning were commercially available until the year 2000. In an extensive collaboration effort between the oil company Statoil ASA (www.statoil.com) and Systems in Motion (SIM – www.sim.no), the geosimulator concept was established using some commercial software as the basis for the geosimulator together with significant software development.

The backbone of a geosimulator is a module containing a digital terrain model (DTM) supplemented with geological information in the form of maps, sections, wells, seismic data, outcrop photos, satellite images, etc. This main module can have links to smaller learning modules (e.g. Microsoft® PowerPoint or Flash® presentations – see www.learninggeoscience.net) on selected subjects, using more traditional presentation methods. Links can also exist to resources outside the geosimulator, usually accessed over the Internet. Parts of the geosimulator concept have already been tested out on university students in connection with a geological field course (Fossen et al., 2001, Hesthammer et al., 2002).

E-learning modules

In a collaboration effort between Statoil ASA and Norwegian academia, initiated in 2000, a number of e-learning modules have been developed. These are interactive, multimedia learning experiences within the sciences of geology, geophysics and reservoir technology (geosciences). The modules contain a mixture of text, figures, pictures, animations, videos and sound. A learner will normally spend 15-60 minutes going through a single module, depending on the level and length. The modules are developed in collaboration between a student and a topic responsible teacher. The student works together with the teacher to create a storyboard from which the module can be developed. This way, the student is paid for developing modules in relation to the topics he or she studies at the university. At the same time, the teacher modernizes the learning material. This provides a win-win situation for both student and teacher.

Qualified modules are published in an online journal (Figure 1) called learningGEOSCIENCE (www.learninggeoscience.net). On the site, users can select modules and also provide an evaluation of the modules. The web site also provides short courses that consist of a selection of modules put into a context.

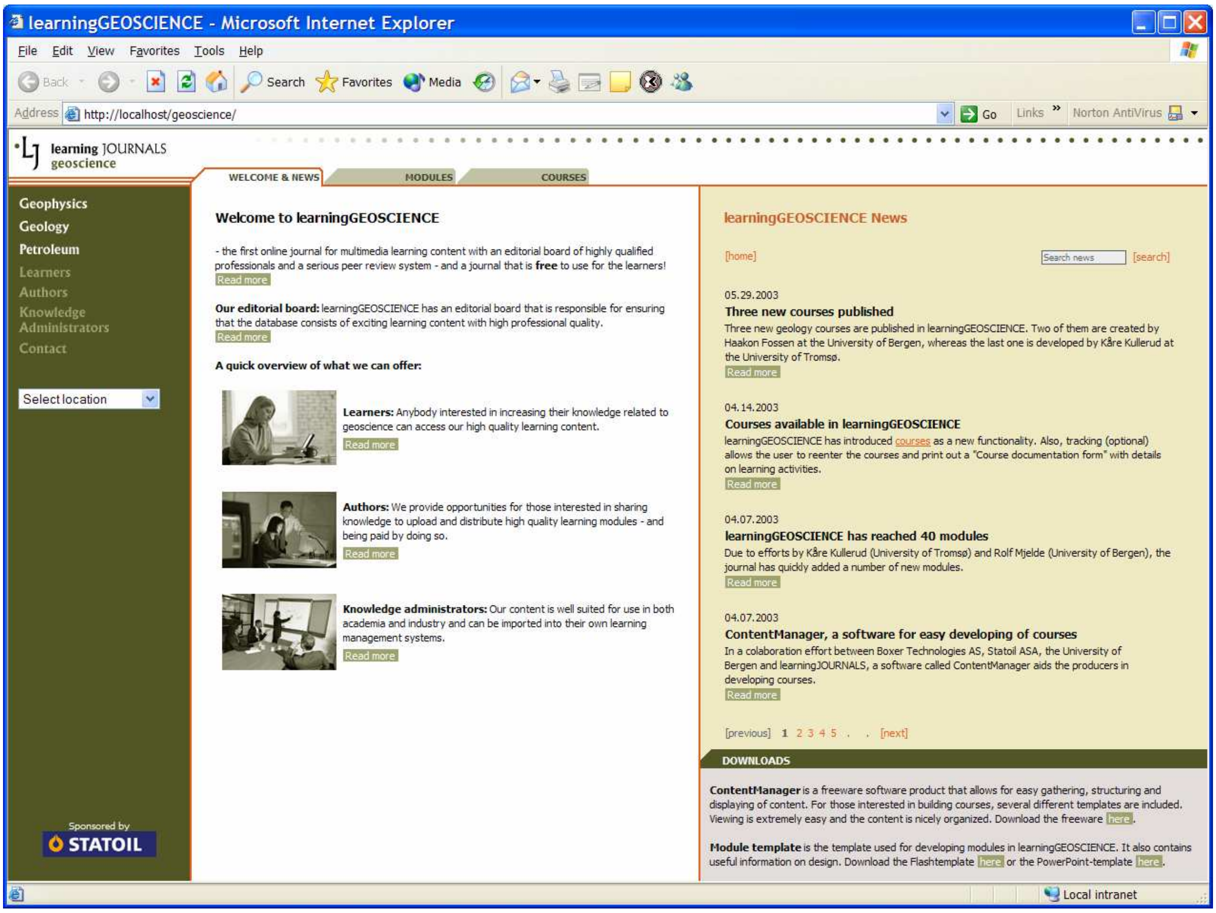

Figure 1: The online journal learningGEOSCIENCE contain e-learning modules and short courses. The content is a combination of text, pictures, figures, videos, animations and sound to provide interactive and multimedia learning experiences.

In the field courses described in this paper, a number of e-learning modules published in learningGEOSCIENCE have been selected to be used as knowledge resources for the field course participants (Figure 2).

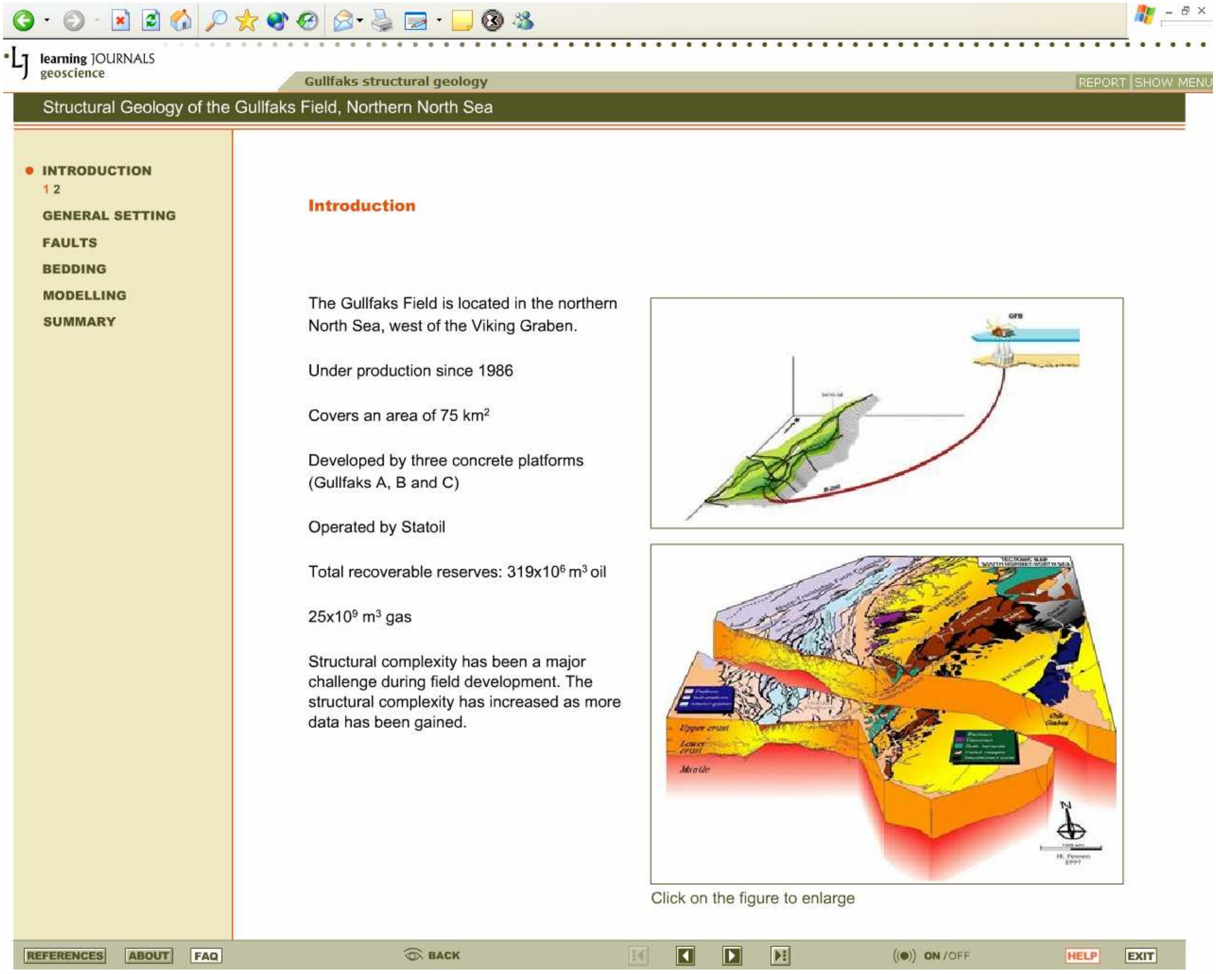

Figure 2: Example page from an e-learning module related to the structural geology of the Gullfaks Field, northern North Sea. The learner can navigate from the menu to the left or using the navigation buttons at the bottom.

Course administration

The use of problem-based learning requires a logical set-up for participants. Since the content needed to be available both in an office- or student environment and in the field, traditional learning management systems were not sufficient. Instead, a tailor-suited content management system was developed. This system is called ContentManager (Figure 3 – freeware that can be downloaded from www.learninggeoscience.net). The system allows the teacher to easily gather relevant files from a computer, structure the course for the participants, and finally viewing and exporting the course so that it can be used by others.

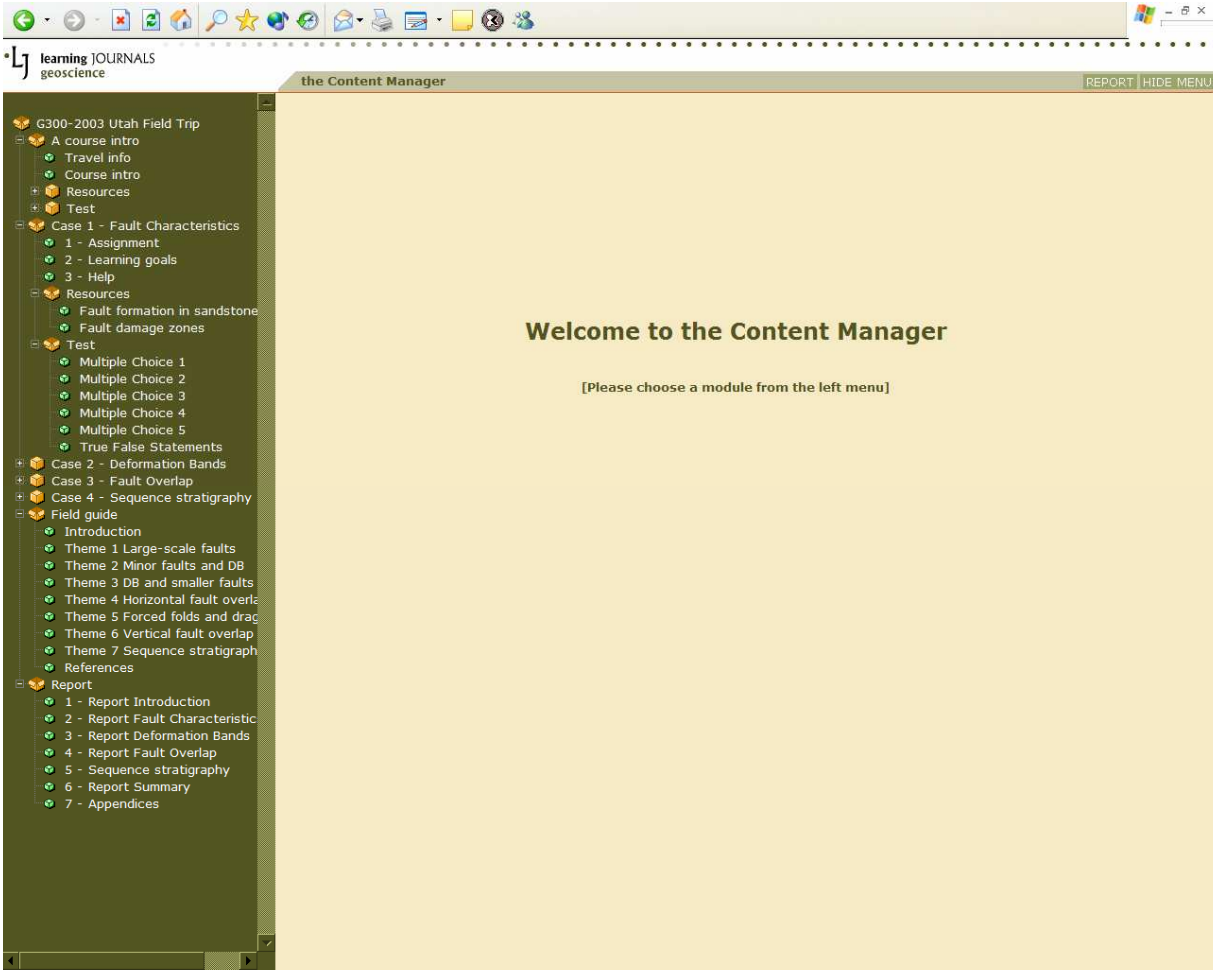

Figure 3: ContentManager is a tailor-suited "personal" learning management system (LMS) that allows tracking and can be used over the Internet and on a stand-alone PC. The software is available at no cost from www.learninggeoscience.net.

ContentManager provides optional tracking of learning activity. This enables the course supervisor to track student activity and test scores. In the courses described in the paper, the students' activities were tracked to ensure that they spent the required amount of time preparing for the field work. The industry course provided content as an optional resource, and no tracking was enabled.

Pedagogy and problem-based learning

The following descriptions of problem-based learning and didactic categories are from Sæther et al. (in print). Problem-based learning (PBL) as a pedagogical method has generated large interest within a range of educational environments, and apparently appeals to both students and teachers. Normann and Schmidt (1992) review the psychological basis for PBL, while Margetson (1993, 1996) discusses the fundamentals of the method. The main characteristics of PBL are also very well formulated by Hård af Segerstad et al. (1999): First, the student is placed in the centre of the teaching process. Second, there is a strong focus on relating the subject in question to a larger context. Third, the student guides his/her own teaching process. Finally, it allows the student to formulate new conceptions together with other students. In PBL both the teacher's and student's role changes. The teacher's role becomes more the tutor's role (Donaldson and Huges Caplow, 1996, and Eagle el al., 1992) while the student must take more control of his own learning.

For the student to be able to take control of the learning process, PBL requires certain prerequisite knowledge and abilities (Naper Jensen in Bjørgen, 2001):

- knowledge about the nature of the learning process
- knowledge about how to search for and use sources of information
- knowledge about how to learn through cooperation with teachers and fellow students
- ability to control the amount of time and effort used in the learning process
- ability to recognize the reality behind the learning goals (curriculum)
- knowledge about how to present the results of acquired knowledge
- motivation for learning and perseverance to complete a study
- self confidence
- creativity

Even though the learning process is the responsibility of the student, intervention and help from a coach in the course of the study is common practice. The coach is usually represented by the teacher, though technology-based coaches have become more common (Johansen et al. in review). Human and technology-based coaches have different qualities and limitations. Bjørgen (2001) notes that both types of coaches lack the ability to exalt learning and that both are totally dependent on interaction with the student in order to succeed.

Didactic categories and relation to the field courses

Kveli (1993) states that: “Each teaching situation is unique and requires its own solutions, though all forms of teaching also have certain elements in common”. Such common elements are termed didactic categories (curriculum elements), and successful teaching depends on the ability to identify links between these categories. Several models provide useful insight into didactic links. A commonly used model in recent Norwegian pedagogic literature is the didactic relation model of Bjørndal and Lieberg (1978). The open nature of this model allows application in all planning and analysis of teaching. The didactic relation model identifies the main didactic categories in teaching:

- student- and teacher requirements
- learning aims
- content
- framework
- evaluation
- learning activities

As noted above, the student is the focus and the student should have the possibility to control the actual learning. Bjørndal and Lieberg (1978) use the term “teaching” in their model, implying an approach which may pacify the student and leave all responsibility to the teacher. This did not pose any problems during the field courses described in this paper and the didactic relation model served as a useful tool in the planning of the courses.

Course requirements

The field course, geosimulator and e-learning modules have been designed for graduate geoscience students at the university and geologists and geophysicists employed in the oil industry. The program is also highly applicable to reservoir engineers, petrophysicists, drilling engineers and management. In addition, the open structure of the geosimulators and e-learning modules also makes the program useful for teachers planning field courses. All participants should have a minimum of insight into how computer tools work. Students at lower levels can also benefit from using the geosimulators and e-learning modules, but preferentially together with a supervisor. The ability of the user to take responsibility for the learning is an important prerequisite. Accordingly, the user must have sufficient knowledge about the learning process.

Learning aims

The learning aims for the field courses were to make students and industry employees understand the characteristics of deformation in porous sandstones and to relate this to how this affects fluid flow and development plans for hydrocarbon reservoirs. Also, the participants should be familiar with basic sequence stratigraphic principles and how these can be related to North Sea geology. It was an objective to let the participants connect structural geology with sequence stratigraphy in order to enable proper understanding of field characteristics.

The participants related location specific observations to the following broader context topics:

- **Fault characteristics**. This is related to what a fault is and how it appears in the field. It includes an understanding of both the fault itself and associated deformation.
- **Deformation bands**. These are small but significant structures that are associated with faults in porous sandstones. They typically restrict fluid flow in an oil and gas field.
- **Fault overlap**. Faults overlap both laterally and vertically. It is crucial for a proper understanding of the characteristics of an oil or gas field to know how faults overlap and how this may enhance or restrict fluid flow across faults.
- **Sequence stratigraphy**. This describes depositional environments. An understanding of these aspects is as essential as an understanding of the deformation characteristics.

An important difference between the student field course and the industry employee field course was that only the student field trip included the concepts of problem-based learning and use of IT in the field in relation to the sequence stratigraphy part. The industry employees acquired sequence stratigraphic knowledge prior to the structural part of the field course, but this part of the course was run separately from the structural part.

Framework and learning activities

The courses consisted of a pre-field work part and the field course itself. The pre-field course for students lasted three days whereas the industry course only had one day of pre-field work. Participants in both the student and industry employee field trips were presented with problems related to fault characteristics, fault overlap, deformation bands and sequence stratigraphy (only students were subjected to the last topic). Each case (or problem) contained an introduction to the case and relevant learning goals (Figure 4). Based on this, the participants would acquire necessary knowledge in order to fulfill the learning goals.

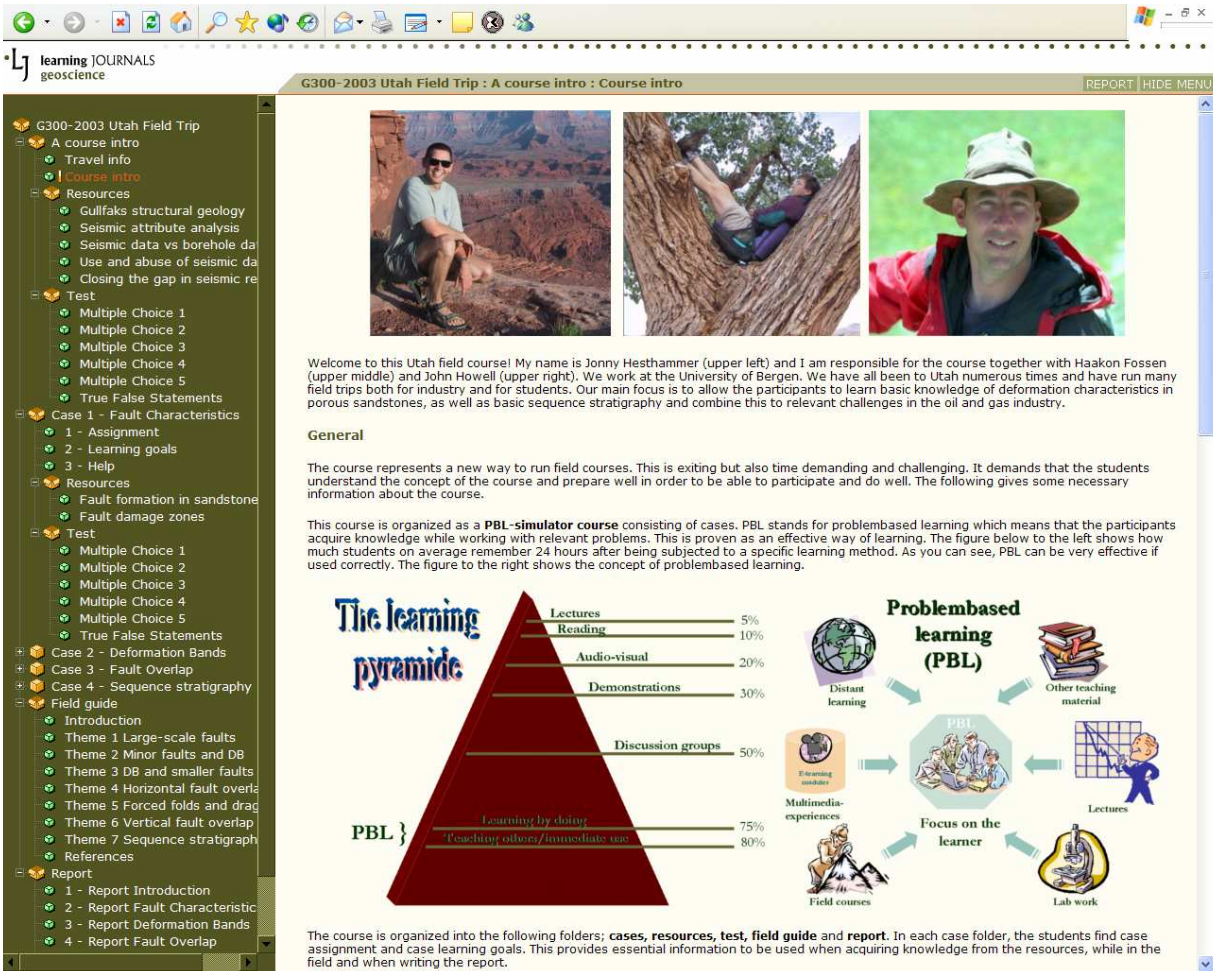

Figure 4: The student field course contained four cases. Each case consisted of an assignment, learning goals, test questions and a resource folder with e-learning modules. In addition, the field guide was available both in digital and paper format. After the field course, the students would write a report for each case.

The necessary knowledge for the student field course was mainly available in the form of relevant e-learning modules, but also as optional articles. These were located in resource folders in the content management system. After having looked at the resource content, the students should be able to understand enough to participate in the field trip. To ensure this, the students would answer test questions related to the main topics. If the students were able to answer the questions, they could rest assured that they had gained knowledge related to the most important goals set forward for the case. The students could decide themselves if they wanted to go through the modules in the groups established or on their own. However, the test questions where mainly meant for collaboration work. At defined times (morning and afternoon), the course supervisor used the geosimulators to introduce the students to the relevant field locations both with respect to geography and geology. The field guide was provided both in digital format (in a resource folder in the content management system) and in paper format for use in the field.

The industry course consisted of a one day pre-field course. Since several of the participants were not familiar with basic geological concepts, the course supervisor gave a basic lecture of deformation in porous sandstones. The geosimulators were used to show locations and discuss basic geology. Towards the end of the pre-field course, the participants worked in groups discussing relevant problems for the gas field they worked on and how the field trip could help increase their understanding of the challenges that lay ahead. The course was made available in ContentManager where the participants could find additional resources in the form of e-learning modules and articles. However, it was optional for the participants to use these resources. Although test questions were provided for the industry employees, there were no obligations to answer the tests. Similar to the student field course, the field guide was provided both in digital and paper format.

In the field, the students were divided into groups. The emphasis was that each group should contain both sexes in addition to a mixture of topic background (structural geology, sedimentology etc.), ages and number of years studied. The industry employees were divided into groups with the focus that each group should contain people with various backgrounds (drilling engineers, geologists, geophysicists, petrophysicists, completion engineers and management).

At each field location, the participants would start off working in groups with little information from the supervisors, except practical details, related to the site

(Figure 5). They would use the field guide, draw sketches and discuss the location specific questions provided in the field guide as well as the broader context questions provided in ContentManager (also available in paper format). For the student field trip, one group would be responsible for documenting the field day. This group would gather information and pictures, using a digital camera, from the different localities. In the evening, the group would develop a Microsoft® PowerPoint-presentation which would be presented the next day by the group.

Figure 5: Student groups working at a location discussing case-specific and location-specific problems.

During the group work at the specific locality, the course supervisors would help the different groups by guiding them and providing key questions for discussions. Towards the end, all groups would come together for a common discussion about results and key observations. This session was led by the course supervisors (Figure 6).

Figure 6: Towards the end of a location visit, the participating groups gather together for a common discussion of both location-specific and case-specific problems.

The industry employees would work much the same way as the students. However, no group was responsible for documenting the day. This was taken care of by the course supervisors. The reason for this difference is related to the need for students to qualify for course units, as well as practice in preparing and presenting material orally. Industry employees are more familiar with this type of work conditions. In addition, it was a main focus to bind the industry employees together, a purpose which would be hard to accomplish by having one group work each evening.

Before going out in the field, each day started with a summary of the previous day's lessons. The course supervisors would use the geosimulators to "debrief" the groups as well as to show them the localities that would be visited that day. This was done in one of the motel rooms using a portable computer and a video projector. A regional geosimulator was used to provide an overall understanding of locations, whereas detailed geosimulators provided the necessary information about each locality.

For the student field trip, the group responsible for synthesizing the previous day's work would give their presentation to the other groups (using the portable computer and showing the Microsoft® PowerPoint presentation on the wall using the video projector), whereas the course supervisors would undertake this work for the industry employees.

After the field trip was finished, the industry employees had no more responsibilities. This is somewhat unfortunate since a report would help them organize and provide a fuller understanding of the knowledge acquired in the field. However, it was felt that the work load upon return to their jobs would be in conflict with a demand for a final report. In the future, this should probably be considered in light of the costs involved in arranging a field course for industry employees. These are considerable, and can only be justified by arguing for a long term investment that will lead to cost-effective field development. In contrast, each student group was required to spend three days documenting the field course in a report upon return to the university. The report was not locality specific, but focused on the main topics (one chapter for each case).

Both the industry employees and the students have access to the field content provided in ContentManager after ending the field trip. This provides opportunity for indulging in the field-related content at a later stage, although it is uncertain if the participants will choose to do so.

Evaluation of participants

There was no evaluation of the industry employees after the field trip. The students, on the other hand, must demonstrate that they have acquired the necessary knowledge found in the resource folder by answering the test questions. Content Manager would register the test results and the e-mail address of the individual student or the group (the students could decide themselves if they wanted to provide answers individually or in groups – if answered individually, the course supervisor would have the opportunity to evaluate the student's acquired knowledge by an oral test). Students that could not demonstrate that they had acquired sufficient basic knowledge prior to the field trip, would not be able to participate in the field trip. In order to obtain credit units for the course, the students had to participate in all parts of the course and also be able to provide a report of sufficient quality to demonstrate that they fulfilled the requirements set forward in the learning goals. There were no grades associated with the course, only "passed" or "not passed".

When evaluations are based on written reports, it has been shown that Internet-based students avoid use of illustrations, primarily because these do not count during an evaluation. However, for visual presentations to come to proper use, evaluations must properly acknowledge the use of such material (Bjørgen, 2001). This is simplified in the current field course since the students have already acquired necessary material into Microsoft® PowerPoint presentations (both text and pictures).

Course evaluation by participating groups

An evaluation form was provided for each of the participating groups during the last field day. For practical reasons, the evaluation form was handed out to each van so that they could spend time filling out the evaluation form while driving to the last location. This provided a time span of more than an hour to fill out the evaluation sheets. Since the students where mixed in the vans, more than one group added to each evaluation form. For the industry employees, each van represented a group.

The evaluation form was developed in order to provide feedback on both the pre-field course and the field course. The groups evaluated the course with grades and comments. The grades ranged from 1 (poor) to 6 (best) with respect to the following aspects:

1. General
2. E-learning modules (only students)
3. ContentManager (course administration)
4. Group work/method (PBL)
5. Use of two supervisors rather than one (only industry employees)
6. Preparing and giving presentations (only students)
7. Simulators
8. Focus on topics rather than localities (only students)

A brief summary of the main evaluations are given below (grades are average of groups).

Pre-field course

- **General**:
  - *Students*: 5. One group felt that the three day long pre-field course was too extensive. In general the groups felt that it was good with pre-field course preparations.
  - *Industry*: 4.9. All groups felt that the pre-field course was needed, using comments such as "a pre-field course is necessary due to the large variations in background knowledge".
- **E-learning modules (only students):**
  - *Students*: 4.5. One group felt that the distribution of modules with respect to cases was unevenly distributed. In addition, the group felt the need for a dictionary translating some terms from English to Norwegian. Another group commented that "the modules were highly informative and well built". One of the groups lacked modules related to sequence stratigraphy (Author's comment: the sequence stratigraphy part was documented in the form of pdf-documents rather than e-learning modules). One group also commented that some of the modules could be improved with respect to text size, figure size and more.
- **Use of simulators:**
  - *Students*: 4.75. One group stated that the benefit was greatest while in the field. Other comments were: "very useful with overview before entering the field" and "it is very important with an understanding of location which the simulators provided".
  - *Industry*: 5. All groups felt that this was important although one group wrote that "the animations on the portable computer was at times somewhat slow"
- **ContentManager (course administration)**
  - *Students*: 4.75. One group lacked the ability to print out the information for use in the field. The groups felt that the administration was good and simple and gave a good overview of the content.

- *Industry*: 5.2. The groups found the content administration useful. One group stated that "it is very nice too have this accessible on the Internet" and that "although not used much prior to the field trip, it provides an opportunity to look at the content after the field trip".

- **Focus on topics rather than localities (students only)**
  - *Students*: 4.75. Although two of the groups had problems considering this question prior to writing the field report, 3 of the groups felt that it was correct to focus on topics rather than localities for summarizing main points. One group wrote that "it is very good with focus on larger context topics rather than localities", and another stated clearly that "it is highly recommended that the report focuses on topics rather than localities".

Field course

- **General**
  - *Students*: 5.0. The students were generally satisfied with the field course. Several of the groups felt that some of the days were too long, something that affected the preparations of the presentations the students were to give the next morning. One group wanted an extra day off in the middle of the one week long field trip.
  - *Industry*: 5.4. One group stated that "it is good that the summary is given the next morning and not the same evening". In general, all groups indicated that they were happy with the course. Some of the groups felt that it was too much focus on deformation bands which was one of the main topics (Author's comment: Several of the participants were not geologists, which is probably the reason for this statement). One group felt the need for an extra day off in the middle of the one week long field trip.
- **Use of simulators:**
  - *Students*: 5.0. Two of the groups noted that the simulators were more effective in the field course than in the pre-field course. One group felt that it was "good to know where the localities were but that there was a little too much repetition".

    - *Industry*: 5.25. Comments were “very good”, “very nice to see connections between localities”, “highly useful with debriefing the next day”, and that “it took the supervisors somewhat long to find some of the locations in the simulator”.
- **Group work/method (PBL):**
    - *Students*: 5.0. All groups felt that the group work enhanced the learning effect. Comments were that “this is very good and we are very happy with the concept. It was fun to work in groups and we learned a lot”, “four people in a group are good as it avoids having two against one”, and “it is good with the group discussions”. One of the groups stated that they had some internal personal problems. It was also noted that, although precautions were taken to mix the groups, it was not entirely successful for all groups.
    - *Industry*: 5.7. This is the highest average score given in the evaluation and the comments were “very good to involve everyone”, “the problem-based approach had a good learning effect”, “the groups where mixed in a good way”, and “the supervisors provided good guiding of the groups”. All groups were satisfied with the work method.
- **Use of 2 supervisors as opposed to one (industry only):**
    - *Industry*: 4.7. All groups felt that this was a good approach and that the supervisors worked fine in conjunction. Two groups stated that “it is necessary with two leaders when problem-based learning is used in order to allow discussions with the groups”. A third group commented that “the use of two supervisors provides more opportunities for discussions with groups, which is good”.
- **Preparing and giving presentations (students only):**
    - *Students*: 4.5. All the groups appreciated the preparation and oral presentations of the previous day’s highlights. One group stated that “this was a good idea and less knowledge would be acquired if this was not done”. The same group also stated that “sitting in a car preparing presentations is not the best way” (Author’s comment: Two of the groups had to make the presentations in the field due to camping out – the presentations were later given in an auditorium at a museum). One group

stated that “students present the knowledge in a different way than the supervisors, which is good because it provides variety”.

Discussion

There are significant differences between a student field trip and a field trip for industry employees. Whereas the industry employees have their focus on job-related aspects, the students have no or little industry experience. As a result, industry employees tend to learn in relation to value chain and work processes whereas the students learn in relation to more basic science disciplines. However, there is a clear connection between the two as illustrated in Figure 7. Also, whereas the industry employees have their focus on competency (the ability to do a specific task the correct way), the students focus on acquiring basic knowledge.

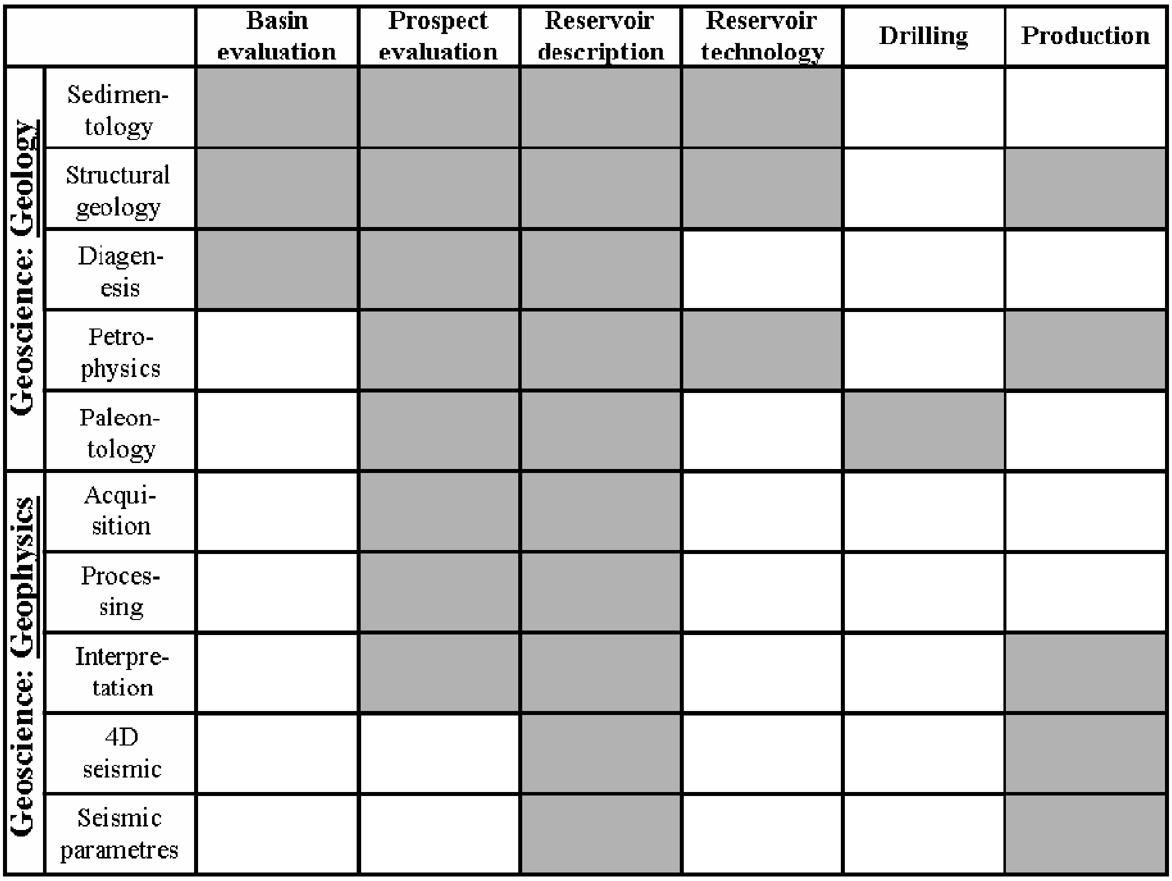

Figure 7: Industry employees typical focus on knowledge in light of the value chain processes. University students tend to focus more on the basic science disciplines as they have little or no industry experience. But there is a close connection between the two approaches. In the figure, grey boxes suggest where value chain processes overlap with science disciplines.

Considering these basic differences, there are surprisingly many similarities with respect to how the participants rate the field course both with respect to pedagogic principles and the use of modern technology and the main points are discussed below:

- A pre-field course will likely enhance the learning effect significantly as it prepares the participants for the knowledge they will acquire in the field. It is therefore no surprise that the participants in both courses felt that the pre-field course was needed. It is also likely, although not evaluated, that the requirement to write a report after the field trip will enable the participants to observe the acquired knowledge in a larger context. As such, it is unfortunate that the industry feel that they can not allow the time needed to write a report (1-3 days).
- The use of problem-based learning in groups requires that enough resources are available to supervise the groups. The purpose of letting the participants work in groups is to stimulate discussions and allow learning by making use of the knowledge they acquire in relation to the problems defined. In order to allow for this, the supervisors need to guide the groups at the different field locations. There is no doubt that both students and industry employees found the group work highly valuable. The very high rating from industry employees is likely related to the basic knowledge of the participants. Several of the participants where unfamiliar with a basic geological understanding. Since each group contained one or more geoscientists, it was possible to allow discussions that probably would not occur in a plenum setting.
- The participating groups in both courses appreciated the availability of content in a simple content management system that was available both on the internet and as a stand-alone system on PC's. The use of a simple tree-structure to display content is appreciated by the learners as it is familiar to them (similar to Windows® Explorer). The use of tracking was considered positive by the students as it gave them freedom to go through the content anywhere and at their own leisure.
- Based on the feedback, there is no doubt that the field simulators were useful for the participants whether they were students or industry employees. Perhaps not surprisingly, the feedback was most positive for use of field simulators

while in the field. This gives closeness to the locations both with respect to space and time. Although the simulators contain many resources (pictures, maps, seismic horizons, profiles), it was the overview of the area that was brought forward as the most important aspect.

- The students gave a positive feedback on the use of e-learning modules. In fact, the course contained a single pdf-document and some students commented in the feedback that they would very much like to see this document converted to an e-learning module. This feedback is important as there is still much debate on the limitations of knowledge that can be acquired by the use of modern technology. Obviously, processes can be illustrated with animations. Also, having easy access to digital learning material is appreciated by the learners.
- The focus on topics rather than localities was also much appreciated. The students obviously felt that this approach was best for obtaining a fuller understanding of the main topics to be learned. Although perhaps not surprising, the reader must keep in mind that most field trip reports are still written as diaries based on localities.
- Due to the long field days, the authors did not expect a very high rating on the aspect of late evening work by one group in order to prepare a presentation for the rest of the groups the following day. However, the feedback was clear in that students liked this approach. This is partly related to the repetition aspect but also to the aspect of competition. The students want to present good results and are willing to sacrifice an evening in order to do so. In addition, the feedback shows that the students like to obtain a summary from others, not only the course supervisors, as this provides repetition in a different way.

Conclusions

Based on the feedback from the two geological field courses in Utah, one for industry employees and one for students, there is little doubt that the use of modern technology in the field can enhance the learning effect if used correctly. E-learning modules provide an attractive alternative to text-based documents and lectures. In particular, animations can be used to demonstrate processes that would otherwise be difficult to comprehend.

The use of geosimulators allows participants to obtain an overview of an area prior to, and after, being to a specific field location. The use of such advanced flight simulators are most appreciated when used in the field due to the closeness to localities with respect to time and space.

Problem-based learning, where the participants work in groups solving topic- rather than location-specific problems, is clearly favored by the participants. They feel that they learn more by being challenged at each locality and by sharing knowledge through discussions. However, the use of group-related problem-based learning in the field demands that enough supervisors are available for guiding of the groups. Each of the current field courses had approximately 20 participants. One supervisor is clearly not enough to sufficiently guide the groups. This must be considered before deciding to use problem-based learning in the field. For the industry, this must be viewed in light of investment rather than cost, although the answer should be fairly obvious. For academia, every possible effort should be made to have enough supervisors available.

The use of a pre-field course enhances the learning effect as it prepares the participants both with respect to locations and topics. In a pre-field course, the learners can acquire knowledge from e-learning modules and get an understanding of the field area from the advanced flight simulators. Similarly, writing a report after the field trip enables the participants to collect their thoughts and obtain a fuller understanding of the larger context. As such, it is unfortunate that such reports are only required on student field trips.

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