

Using geosimulators to enhance field-based geological training

Bjørn Sæther¹, Ståle Emil Johansen², Jonny Hesthammer³, Olav Solbakken⁴ and Kari Ellen Synnøstvedt⁵ explain how the pioneering use of computer technology can enhance field training in the geosciences for both university students and oil company personnel

Introduction

Extracting information from outcrop geology is essential to understand geological processes, consequently field work and field courses have been a traditional part of geoscience university courses. 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.

This paper describes a pioneering project where computer technology is an integral part of field training. By combining a wide range of geological and geophysical information in a specially designed computer package, SVALSIM, it is possible for field students to participate interactively in the learning process. SVALSIM comprises a digital terrain model (based on the technology of flight simulators) supplemented by various types of geological information, including geological maps, profiles, field photos, well logs, seismic data, as well as sound and movie clips and traditional text-based material.

An example of how the technology can be implemented into geological field trips is described by Hesthammer *et al.* (2002). There are also external links to additional information on selected subjects available on the web (www.sim.no and www.learninggeoscience.net). Parts of SVALSIM are illustrated on web sites www.statoil.com (under Topics, Geo 2000) and www.scanviz.org/Media/SvalSim.htm.

Traditional field-based learning in geosciences

Geoscientists must understand processes on a wide range of scales, from regional basin evolution through micro-scale mineral reactions, 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 programme lasting one to two

weeks, focusing on a number of localities (Figure 1).

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 supplied in advance to allow the students to prepare for the exercises they will go through in the field.

University students normally present field work results in the form of a

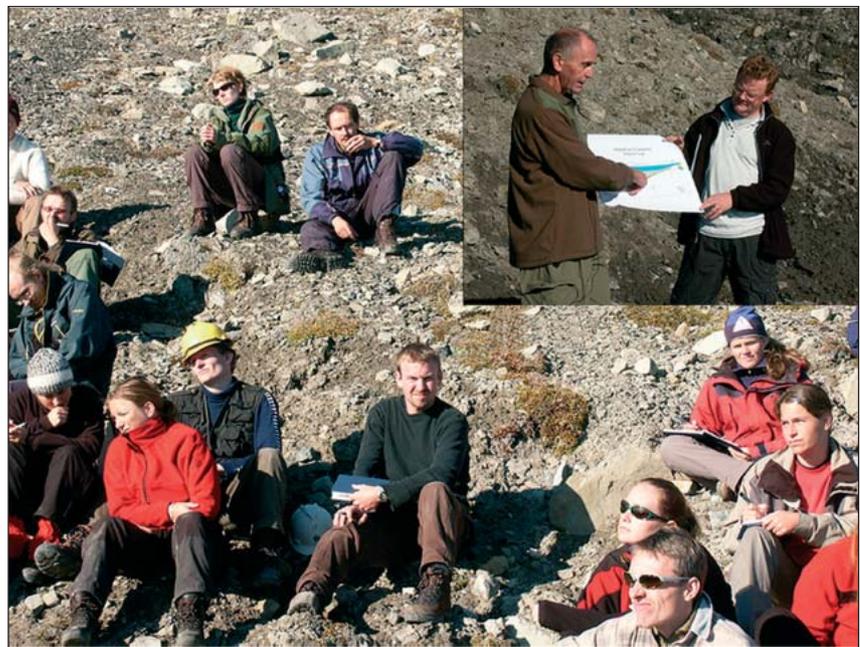


Figure 1 Students gathered close to an outcrop on Svalbard (Spitsbergen). The professor introduces the challenges at this location before the students start their self-study.

¹Statoil ASA, Research and Technology, Postuttak, N-7005 Trondheim, Norway (bsae@statoil.com)

²Norwegian University of Science and Technology, Department of Petroleum Engineering and Applied Geophysics, S.P.Andersensveg 15 a, Valgrinda, NO-7491 Trondheim, Norway (staaleej@online.no) ³University of Bergen, Department of Earth Sciences, Allégaten 41, NO-5007 Bergen, Norway (jonny.hesthammer@geo.uib.no). ⁴Gaviatech, Overlege Brattsveg 66, NO-7027 Trondheim, Norway (OSO@gaviatech.no) ⁵Opplæringskontoret, Melhus kommune, NO-7224 Melhus, Norway (KariEllen.Synnøstvedt@Melhus.kommune.no)

written report after the course, while professionals often present their results in the form of short lectures while still in the field. Field reports can be quite extensive and are often included as parts of university degrees.

Digital terrain models in field-based learning

The idea behind a geosimulator like SVALSIM (SVALbard geoSIMulator) was to establish a tool which made it possible to do 'realistic' field training on a computer, as an aid before, during and after the actual field activities take place. Though the aim of SVALSIM was to strengthen field work, not replace it, it was also designed for use on a stand-alone basis. There exist numerous programs for 3D visualization, e.g. GIS systems, but no software packages aimed at applying digital terrain models (DTM) in field-based learning were commercially available at the onset of the project. Some commercial software was used as the basis for developing the geosimulator concept (see www.sim.no under Geo2000), but most of the computer program had to be created from scratch.

The backbone of SVALSIM is a module containing a digital terrain model (DTM) of the Arctic islands of Svalbard (Spitsbergen), supplemented with geological information in the form of maps, sections, wells, seismic data, outcrop photos, satellite images, etc. This main module has links to smaller e-learning modules (Hesthammer 2003) on selected subjects. Links also exist to other resources outside SVALSIM, usually accessed over the Internet. Parts of the SVALSIM concept have already been tested out on university students in connection with a geological field course in Utah where a digital terrain model in the form of an advanced PC-based flight simulator provided overview and insight into specific field locations (Fossen *et al.* 2001, Hesthammer *et al.* 2002).

The SVALSIM user interface was designed to meet two main goals. First, the student should experience a learning process based on visual observation

and active participation that is similar to traditional field work. Second, the student should be able to influence how the program is used and take responsibility for his or her own learning schedule. The whole development process took a total of two years. Tools like SVALSIM are based on the pedagogical principles of experiential and problem-based learning, i.e. learners solve tasks by travelling around in the virtual landscape looking for geological information or geophysical data. The objective of this learning will normally be defined by an instructor, but choosing the way of learning or how to find the relevant data should be the students' responsibility.

Responsibility for own learning

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, the teacher and student roles change. The teacher's role becomes more the tutor's role (Donaldson and Huges Caplow, 1996, Eagle *et al.* 1992) while students must take more control of their own learning. For students to be able to take control of the learning process, PBL requires certain prerequisite knowledge and abilities (Naper Jensen in Bjørgen 2001).

Didactic categories

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. A commonly used model in recent Norwegian pedagogic literature is the didactic relation model of Bjørndal and Lieberg (1978) which identifies the following categories:

- Student and teacher requirements
- Learning goals
- Content
- Framework
- Evaluation
- Learning activities

Student and teacher requirements

SVALSIM, including sub-modules, has been designed for graduate geoscience students at university and geologists and geophysicists employed in the oil industry. The program should also be applicable to reservoir engineers. In addition, the open structure of SVALSIM makes the program useful for teachers planning field courses, not only at Svalbard. All users must have a minimum of insight into how computer tools work. Students at lower levels can also benefit from using the program, but preferably together with a supervisor. The ability of the user to take responsibility for the learning is an important prerequisite.

Learning goals

Five learning goals have been formulated for SVALSIM:

- To learn basic geology through understanding the geological history of Svalbard (Spitsbergen)
- To understand selected geological processes
- To understand the link between geophysical measurements, analytical methods and geology
- To learn field work methods
- To understand the link between geological evaluation and business potential

Framework

SVALSIM should be useful before, during and after field work. It should also

be possible to make use of the program without doing actual field work. To be used during field work, SVALSIM must be compatible with portable computers. Furthermore, SVALSIM must allow for both individual and group work, in offices and in the field, and should be designed for field courses lasting approximately one week.

Evaluation

One evaluation method involves the student being asked to produce his/her own learning modules (Hesthammer 2003) in Microsoft PowerPoint, and is based on formal requirements regarding the content and design of the modules. This form of evaluation is applicable to all types of SVALSIM use. A second evaluation method is based on the student incorporating new field work results (digital photos, video, graphics and text) into SVALSIM.

Learning activities

In SVALSIM the student moves around in a virtual, flight simulator-based, Svalbard landscape searching for geological knowledge. The shapes of the landscape itself provide the student with new geological information. Integrated in the 'real life' landscape is a virtual geological knowledge environment where the student must perform learning tasks to build up his/her own knowledge. Learning tasks are sometimes defined by others (assignments), while in other cases the student is left alone to choose how and what to study. An important prerequisite in the planning of SVALSIM has been that the program should exert little control over learning activities.

Design and production of SVALSIM

In the design of the virtual learning environment, we have emphasized that the terrain should appear as realistic as possible. This is most easily done using the concept of well-established flight simulators (e.g. Microsoft Flight Simulator). One of the main challenges has been to make it possible to work with very large datasets on commercially available per-

sonal computers (Intel-based machines), without experiencing long response times. At the same time the system must also be compatible with presentation on large screens, even in 3D, using stereographic glasses, run by high performance graphical systems (SGI).

The size of the digital terrain model grid in SVALSIM is 22000 x 27000 data points, which results in a model with more than one billion triangles. To work with this amount of data on a relatively small computer (512 MB RAM), data reduction is required. Data reduction is done by continuous 'true time' rendering which ensures that sufficient detail is available when needed. This block-based data reduction method works well when run on disks with good search-and-transfer properties. Error tolerance can be adjusted at any time while running SVALSIM.

Generating a realistic virtual terrain involves the draping of pictures or textures, which is relatively simple on Svalbard due to the lack of vegetation. By taking altitude, inclination and orientation of hillsides and glaciers into account we have generated a 'summer texture' for Svalbard. Various textures can be draped on the digital terrain model. In SVALSIM, two global textures are implemented: 1) a satellite image texture (Landsat) and 2) rock ages in colour codes (Figure 2).

The user interface is implemented as a Global Positioning System (GPS) console, which can be adjusted according to special user needs. In the vicinity of field localities, resources designed for that particular locality are automatically made available. Navigation requires a standard three button mouse, but can also be done by joystick or space ball. The interface is very simple and intuitive: (1) a navigation window shows the coordinates, elevation and speed (when 'flying'), (2) available waypoints (geographical places) where (3) resources (local data) are available (Figure 3). Some data are global and available wherever the user travels; some data (resources) are local and available only close to specific locations (waypoints).

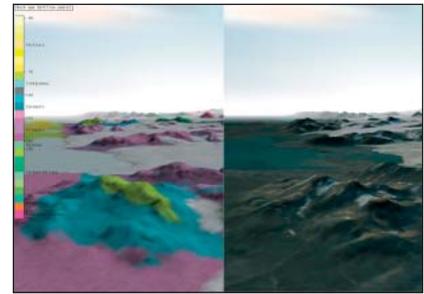


Figure 2 Two screen dumps from the SVALSIM. The artificial sky dome and the effect of distant areas made more foggy can be seen. The texture to the right has a satellite image texture. The same area, to the left, has a texture of colour coded rock ages.



Figure 3 The interface is very simple and intuitive in use. Left menu is a navigator, informing the user of position, view elevation and speed when 'flying'. Middle menu lists waypoints, or placed where local data (resources) are available. When clicking on a waypoint, the simulator automatically positions and makes local resources available. These local data can then be chosen by clicking in the right menu.

Other data types than terrain and texture can be imported as virtual reality modelling software (VRML) or similar formats, which is the simplest way to include measurements or simulations performed by the user during operation. Measurements and simulations typically comprise magnetic and gravity data, geological profiles and sections, maps and interpreted seismic lines.

Data reduction with minimum loss of visual quality is done by use of Rational Reducer software produced by Systems in Motion (www.sim.no). Objects can be placed in the terrain in locked positions or can be placed to allow movement by the user. Geological

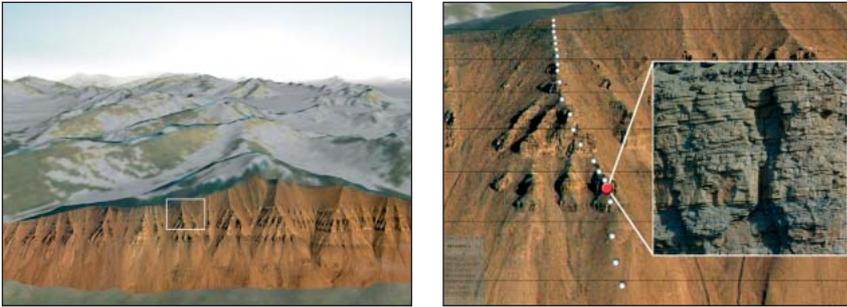


Figure 4 a) *The Van Keulen Fjord, looking north. A picture mosaic of the mountain Storvola is activated; b) a detailed look with white dots marking places with detailed images.*

cross-sections (profiles), generated as part of geological mapping or research can be pulled out of the ground when needed, and pushed back down again after use. SVALSIM supports placement of digital photos anywhere in the terrain model. The system also supports the addition of text and graphics to these photos, which can be turned on or off according to need. Specially detailed textures can also be placed locally, to allow the user to work with more detailed geological information on selected localities (Figure 4). Resources also include a logging tool which allows the user to interactively log and describe sedimentary sections, by use of observations at all scales just as in ordinary field work. Another example of interactive use of the geosimulator is performing measurements of magnetic data. This enables correlation between magnetic measurements and rock properties (Figure 5).

During two field seasons petrophysical (gamma ray, magnetic susceptibility, acoustic velocity and density) data from a 200 m section at Festningen was collected and incorporated into the simulator. The geosimulator gives additional information to the field work, since data is implemented and referenced by detailed images (Figure 6). At this and other localities video clips are also available to allow detailed study of the locality from different directions, aimed at creating a sensation of real life field work.

Other programs which may be useful during virtual field work (e.g. seismic interpretation software) can be booted from within SVALSIM. Links

to separate e-learning modules (www.learninggeoscience.net) can be placed on strategic localities according to relevance. In addition, SVALSIM is also designed to give the user a high degree of freedom as the software solutions are designed for use with a range of hardware platforms (SGI/Irix, Intel/Windows, and Intel/Linux). Most programming is done with Linux in C++ by use of System in Motion's Coin 3D graphics library over 'open GL' code. The Lisp/Scheme Guile implementation was used to ensure easy maintenance, including true time modifications.

SVALSIM was developed by Statoil, but the simulator is made available to all Norwegian universities for educational and research purposes. They are even encouraged to join the further development of SVALSIM. In a separate research collaboration, the University of Bergen has, together with Systems in Motion and Geo2000, developed several simulators for areas in Utah and Colorado, USA. The total cost of this project was limited to \$35,000 and included a digital terrain model with 10 m lateral resolution, satellite images with 30 m resolution, ortho-photos (aerial photographs) with 1 m resolution, topographic maps and selected photographs. These are used in field courses run by the University of Bergen and Statoil (Hesthammer 2003).

Example of SVALSIM in operation

In the summer of 2002, approximately 135 Norwegian geoscience students

performed field training on Svalbard staged by the SVALEX project. SVALEX is a collaboration between Norwegian universities, the graduate school in Stavanger, the university studies on Svalbard (UNIS) and Statoil (sponsoring oil company). The main purpose of SVALEX is to promote cross-disciplinary learning in the field. In accordance with this, geophysics students had important elements of geology and reservoir engineering in their program and vice versa for geology students. All students had access to SVALSIM during preparations for field work, in the field and during reporting after they return home from Svalbard.

Preparations

All participants in the SVALEX field trip have to develop a detailed program for one day in the field, including all aspects of operation necessary for both safety and science in the arctic desert on Svalbard. During planning, the student will need help from a coach. This could be a virtual supervisor like SVALSIM. By using SVALSIM the students can 'travel to Svalbard' while they plan their stay. They can work with geoscience problems in the simulator, and get prior knowledge of geography, stratigraphy and regional geology in the areas they plan to visit. On some localities they may also get acquainted with more detailed problems, which will save time during subsequent field work. SVALSIM can be run on PCs or in miniature visualization studios supplied to the academic institutions participating in SVALEX.

Field work

Studies by Bates (1992) on Internet-based learning have shown that results are linked to the degree of integration of technological coaches with other elements of the learning program. The field part of SVALEX is based out of a ship. The students live and work onboard this ship for eight days. The ship is stationary during the day and sails between locations at night. There is ample access to technical equipment onboard, including PCs as well as a

miniature visualization studio (to allow 3D visualizations).

By using SVALSIM it is now possible to prepare for activities by going through the program onboard in a very realistic manner. Some localities cannot be visited (due to logistical or weather problems – these problems are commonly related to running a field trip in arctic environments) but may still be important for the program, and these can be run onboard in the studio. Sometimes localities are passed close enough to give a regional overview without going onshore. In these cases SVALSIM can be used to go ‘virtually onshore’ in the terrain model and study various types of geological information including photos and video. This way of using SVALSIM can tie preparations closely to the actual field work.

While on Svalbard and during reporting after the trip the students work in groups of five or six. They have a chance to visit their own selected localities. During field work the students will gather information in the way they find appropriate according to their own planning and preparation.

Reporting and evaluation

Following field work the students are usually saturated with impressions, and the amount of new knowledge gained is highly variable between individuals. New knowledge is usually easiest remembered if linked to personal experiences and actual work. Field learning is particularly demanding because a major part of the learning is done at localities which are only visited once. With the help of SVALSIM the students can return virtually to the locations they have visited, which should be of great help during reporting.

Obviously, the SVALEX students themselves will contribute to the continuing development of SVALSIM. SVALEX will also benefit from this because next year’s participants will draw on the results and experience from this year’s field operations, and have access to even better field learning resources. This way of conducting field learning is thoroughly evaluated by all

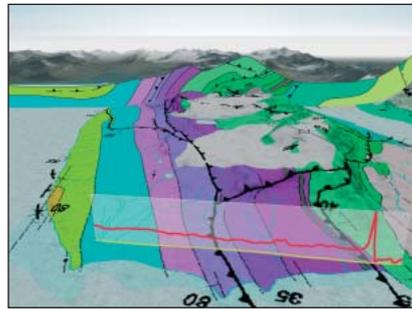


Figure 5 At the Festningen, southwest in Isfjorden, the layers are close to vertical, making this location attractive as an analogue to drilled wells. A geological map is draped onto the terrain dividing the landscape into rock units. A geological vertical profile is placed at the back of the terrain. Magnetic data are implemented in the Svalsim geosimulator, allowing the user to ‘measure’ these data (red curve).

participants, both those responsible for the program and the students. This provides for better insight into how technical coaches can be used optimally during field learning.

Experience from SVALEX

According to one of the teachers on the SVALEX field trip in 2002 (Arild Andresen pers.comm.), the teacher and geology students from the University of Oslo used SVALSIM extensively in preparing for the field trip. The simulator was also used onboard the expedition ship. As very few of the students had been on Svalbard before, SVALSIM was used by the students to make them familiar with the geography and regional geology, through videos and high quality colour pictures of field locations. Andresen found the large number of easily available geological cross-sections particularly useful. The videos and the many pictures became very useful during days with clouds, snow and poor visibility.

The following includes some comments from some of the participating students on the SVALEX field trip in 2002:

‘It was easy to learn how to use SVALSIM, but I needed some time to be familiar to traveling around in the virtual landscape.’



Figure 6 At the Festningen, a 200 m section along the shore, a petrophysical log is measured and implemented in SVALSIM. In the image, white dots show where these data are sampled. When clicking on one of these dots with the left button, it turns red and shows the measurements in a yellow image (gamma measurements, magnetic susceptibility, velocities and density). Clicking on the right button shows a detailed image of the sampling spot.

‘The system was very easy to use: after 15 minutes of training I could operate SVALSIM and travel around.’

‘I used SVALSIM both before and on SVALEX 2002. Prior to go to Svalbard we used it to learn the functionality and investigate what kind of data was implemented in the geosimulator. At SVALEX 2002 we used SVALSIM to prepare the visits to the outcrops next day. We also used SVALSIM when we reported the field work.’

‘I got an improved regional geological understanding using SVALSIM. My team also used the geosimulator when writing the reports from each day’s field work. We could use a lot of information in SVALSIM by cut and paste.’

‘I felt that SVALSIM is for special interest people, especially the geologists. The geologists liked the system best. On the other hand, it worked very well when the geologists should explain and work together with engineers. SVALSIM made it possible to teach geology at various levels.’

‘I would like more data implemented in SVALSIM. Since I had been on Svalbard before, the effect was reduced. Going to Svalbard for first time, I believe the effect is good since you can

learn about the localities and get an overview.'

'I used SVALSIM alone and with another student. It was more fun to use the geosimulator in a team. We travelled around and suggestions to go to certain locations popped up. This creative play generated a lot of questions and stimulating discussions.'

Conclusion

By taking into consideration sound pedagogic principles, it is possible to significantly enhance learning by combining information technology and field trips. The digital terrain model presented in this work is not unique for the Arctic islands of Svalbard. Any field location can easily be visualized on portable computers using the technology and principles of SVALSIM. The combined use of many simulators covering different locations and geological themes could enhance further the learning process. The concept can also be used to develop simulators in other sciences such as biology.

Acknowledgements

We thank Hans E.F. Amundsen, Tormod Henningsen, Erik P. Johannessen, Christine Fichler and Winfried Dallmann for their contributions to SVALSIM and Sindre Flatås for organizing security and logistics.

We are grateful to Peder Blekken, Øyvind Rideng and Thomas Hammer, Systems in Motion (www.sim.no) for excellent technical work in developing the field simulator. Asle Strøm at Statoil was responsible for video and photo recording and processing. Stewart Clark, NTNU, did the editing of this paper and Christian Thomassen edited the figures. Special thanks to Statoil employees Hans Konrad Johnsen, Otto Skovholt, Terje Eidesmo (now with emgs) and Martin Bekkeheien – their financial contributions and support have made this project possible.

References

- Bates [1992] (see reference in Bjørgen)
- Bjørgen, I.A. [2001] *Læring: søken etter mening*. Tapir Academic Press, Norway.
- Bjørndal, B., and Lieberg, S. [1978] *Nye veier i didaktikken? En innføring i didaktiske emner og begreper*. Aschehaug, Norway.
- Donaldson, J., F. and Hughes Caplow, J., A., 1996, Role Expectations for the Tutor in Problem-Based-Learning. Paper presented at the Annual Meeting of the American Educational Research Association, April 12, 1996, New York.
- Eagle, C., Harasym, P. and Mandin, H. [1992] Effects of Tutors with Case Expertise on Problem-Based-Learning Issues. *Academic Medicine*, 67, 7, 465-469.
- Fossen, H., Hesthammer, J., Sæther, B., and Johansen, S.E. [2001] Studenter, e-læring og feltefaring: *Geo*, 4, 18-20.
- Hesthammer, J. [2003] How modern technology can meet needs of modern learning in geoscience. *First Break*, 21, 49-54.
- Hesthammer, J., Fossen, H., Sautter, M., Sæther, and B., Johansen, S.E. [2002] The use of information technology to enhance learning in geological field trips. *Journal of Geoscience Education*, 50, 528-538.
- Hård af Segerstad, H., Helgesson, M., Ringborg, M. and Svedin, L. [1999] *Problembasert læring: Ideen, veilederen og gruppen*. Ad Notam Gyldendal, Sweden.
- Kveli, A.M. [1993] *Å være lærer* Ad Notam Gyldendal, Norway.
- Normann, G. and Schmidt, H. [1992] The Psychological basis of Problem-Based-Learning. A review of the Evidence. *Academic Medicine*, 67, 9, 557-565.
- Margetson, D. [1993] Understanding Problem-Based-Learning, *Educational Philosophy and Theory*, 25, 1, 40-57.
- Margetson, D. [1996] Beginning with the Essentials: Why Problem-Based-Learning begins with Problems. *Education for Health*, 9, 1, 61-69.