Computer Utilization in Teaching Earth Sciences: Experience of King Fahd University of Petroleum and Minerals

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The involvement of computers in earth sciences education increased dramatically in the latest decade. At present, several courses in geology utilize software and Computer Based Training (CBT) that help in interpreting and describing the most complicated concepts in very simple ways. This paper presents a general review of computer involvement in teaching earth sciences subjects at Earth Sciences Department (ESD) of King Fahd University of Petroleum and Minerals (KFUPM), Saudi Arabia. The results of a case study are exhibited to reflect the achievements of utilizing computers in the Department. The results are encouraging and support future incorporation of computers in additional geology courses. The experience of ESD in this regard could be taken as an example to develop academic teaching programs in other earth sciences departments in developing countries.

Computer, Earth Sciences, Education, Software, The Internet

INTRODUCTION

Since its establishment in 1963, the Earth Sciences Department (ESD) was the leading department of its kind in Saudi Arabia employing the latest academic aids in its programs. Faculty experience, collection of reputable publications, and modern laboratory instruments were utilized to transfer knowledge to students. Methods used to teach geology courses involve class lectures and laboratory demonstration. In lectures, instructors teach contemporary theories and concepts related to different subjects. In addition, students are exposed to practical exercises in laboratory sessions.

Teaching courses like Physical Geology, Mineralogy and Petrology require explaining the geological processes by which different minerals and rocks were formed, the physical and chemical properties of minerals, and the natural dynamic processes acting in the earth's interior and on its surface. Instructors of Structural and Field Geology courses, usually, train students how to visualize structural features in three dimensions, measure plane attitudes, construct cross sections, and use field equipment. Higher level and more applied geologic courses like Petroleum Geology, Hydrogeology, Geophysics, Environmental Geology, and Engineering Geology discuss different computational techniques and chart-reading methods. Without the aid of computers, instructors need to put great efforts to simplify geologic concepts and assist students

understanding. In addition, students have to spend long time to visualize, calculate, assimilate different geological processes, and interpret a great deal of geological phenomena.

To achieve excellence in teaching, computer utilization was established in early 1980s in ESD. At that time, only a few geology courses took advantage of computer development like Computer Applications in Geology and Hydrogeology. Since that date, academic programs in the Department continue to enhance teaching methods and make them more efficient. For example, many textbooks selected for teaching sophomore- and junior-level courses in geology are supplied with CD-ROMs that have a wide range of illustrations, video-clips, and figures that explain different geological concepts. In addition, a collection of software is, nowadays, available in the Department for different teaching and research purposes. The internet resources and Web-base instructions are, also, important tools used in ESD to augment the teaching process.

The objective of this paper is to shed light on the pioneering efforts conducted by ESD to employ the available computer resources for teaching geology courses and achieve excellence in education. It is also important to mention that the authors are not endorsing any of the software companies mentioned in this manuscript.

COURSE CATEGORIES IN ESD

The use of the computer as a teaching aid has been increased considerably since 1995 until the present time. Appendix A lists both undergraduate and graduate courses that incorporate different computer aids and computational methods as part of their curricula. More information about the courses offered can be found at http://www.kfupm.edu.sa/es/geology/geology.htm. In summary, the geosciences courses are grouped into three categories as is explained in the following paragraphs.

The first category includes courses that utilize computer software in laboratory demonstration and hands-on through problem-solving procedures and data analysis. Examples are courses of Structural Geology, Mineralogy and Optics, Petrology, Sedimentation and Stratigraphy and Petroleum Geology. In these courses, problems that use to be solved manually and consume extensive time become automated and less time consuming. Stereographic projection and directional data plot in Structural Geology, Ternary plots in Petrology, and stratigraphic sections and well logs in Petroleum Geology are examples of such problems. Programs that are used to solve problems in Structural Geology include, for example, *SPLOT* (1988), *ROCKPIX* (1989), and *ROCKWARE* (1995). The *ROCKWARE* package, also, contains several other tools that are used to help students solve problems in Sedimentation and Stratigraphy, Hydrogeology, Engineering Geology as well as Geological Mapping Techniques. Figure 1 displays the common geological applications of *ROCKWARE*.

A second category includes those courses that depend heavily on the computer and cannot be taught without its power. Geologic media characterization and flow simulation courses fall in this classification. Examples of these courses are: Applied Geostatistics, Groundwater Modeling, Computational Methods in Geology, Remote Sensing and GIS Applications in Geology and Hydrogeology. Details about some of these courses and software used to teach them are provided in the next section.

The last category is courses that use computer software, textbooks' complimentary CDs, and the internet as supplementary tools. Educational software greatly helps students to understand different concepts and solve variety of problems. Compact disks (CDs) guide students to learn about and explore different geological processes and systems. *Earth* by Tarbuck and Lutgens (1999), *Geology Today* by Murck and Skinner (1999), *Understanding Earth* by Press and Siever (1998), and *Manual of Mineralogy* by Klien and Hurlbut, (1994) are examples of the textbooks

that use CDs to enhance teaching Physical Geology and Mineralogy courses. Figure 2 shows an example of the front page of an educational CD used to demonstrate geologic concepts. The accomplishment of the Department with regard to Internet utilization is discussed in a later section of this paper.

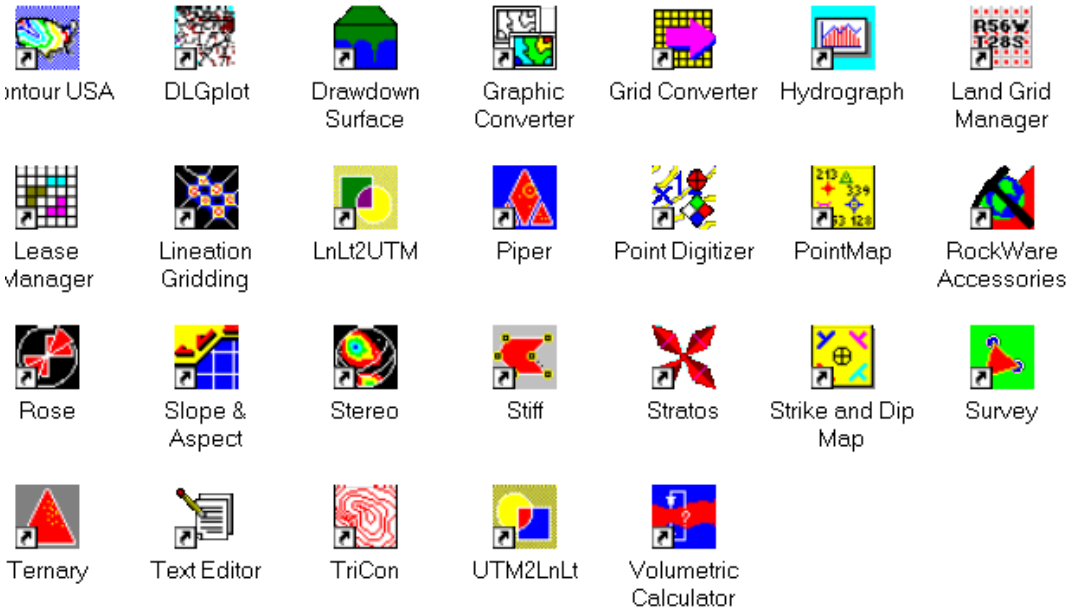

Figure 1. The main menu of *ROCKWARE* (1995) software. This program is used in several courses like Sedimentology, Hydrogeology Structural and Engineering Geology

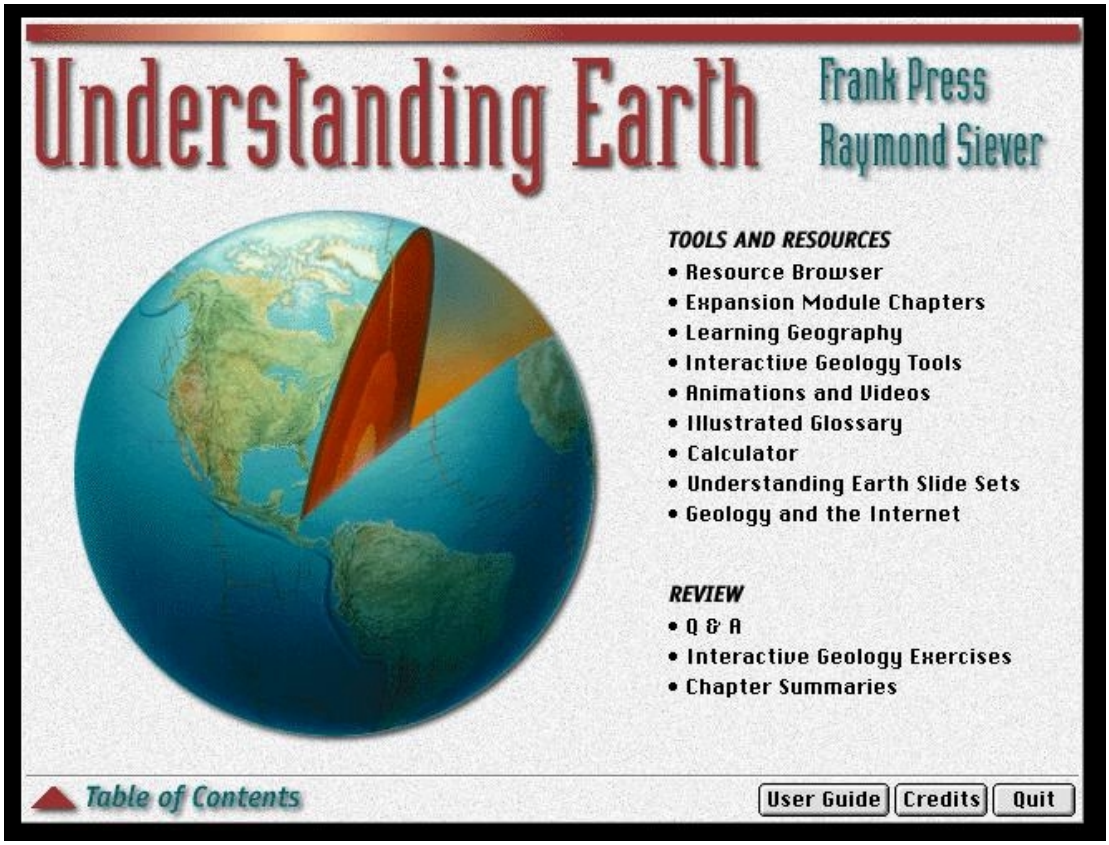

Figure 2. The main screen of *Understudying Earth* CD by Press and Siever (1998)

CHARACTERIZING AND MODELING GEOLOGIC MEDIA AND SYSTEMS

The development and eventual accessibility of high-speed computers, nowadays, are important technological factors that strengthen the relationship between earth sciences and computers. This situation resulted in developing better teaching and interpretive approaches to deal with different geological phenomena. For instance, oil reservoir characterization, water aquifer description, mineral deposit evaluation, groundwater flow simulation, and contaminant transport modeling were considered very tedious and time-consuming fields of study. However, with the power of computes and computation, these topics became more attractive to graduate and undergraduate students. The following two paragraphs describe several available computational tools used to teach students how to characterize and model geologic media and systems, respectively.

Quantitative description of geological parameters in porous media is highly dependent on the correct application of statistical, mathematical, geostatistical, and computational tools (Clyton, 1994). Two courses, in ESD, were designed to provide students with basic and advanced knowledge to deal with geologic media characterization issues. These courses are Computational Methods in Geology and Applied Geostatistics. Examples of the software used to train students on these topics are:

- *WinGSLIB* (*Geostatistical Software Library* for Windows, Ver. 1.3.1) which is a collection of FORTRAN programs that include statistical tools, 2- and 3-D spatial models, estimation procedures, conditional simulation routines, and plotting and printing utilities (Deutsch and Journel, 1998).

- *GS+* (*Geostatistics for the Environmental Sciences*, Ver. 3.17) is a user-friendly windows program that covers most of the important geostatistical tools. Components of the package are: descriptive statistics, semivariogram analysis, block and punctual ordinary kriging, and 2D and 3D mapping (see Figure 3).

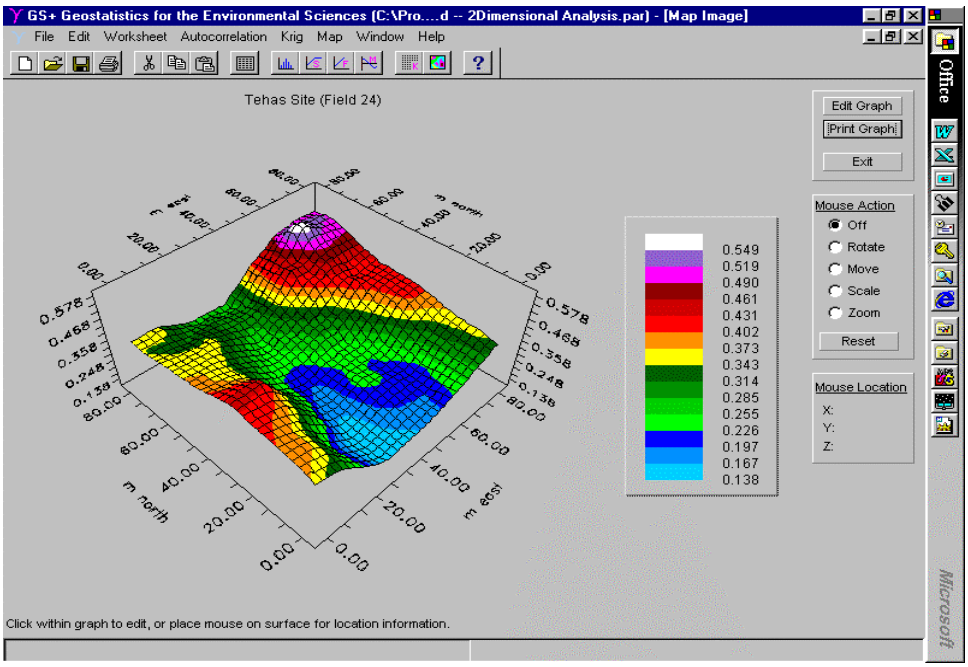

Figure 3. An output screen of *GS*$^+$ (1998) shows the spatial distribution of lead concentrations

- *SURFER* (Ver. 8), which is used to model topography or geologic attribute distribution, is considered one of the most powerful surface-modeling packages. It is dependent on applying

mathematical, statistical and geostatistical techniques to generate the required map and girding system.

In addition to the characterization of geologic medium, prediction of geologic fluid system response to natural and man-made alterations is considered very important to earth scientists. The tool used to measure such effects on a geologic system is called a numerical simulator (Anderson, et al., 1993). Although numerical flow and transport models are widely used in earth-related engineering disciplines, earth scientists are the only professionals who can judge their results from qualitative and physical perspectives. For example, the spatial variability of geological parameters may dramatically affect flow and transport regime in the porous media. Dealing with numerical flow simulators is not only a matter of plugging-in and changing input parameters to match the historical records of aquifer responses, but also of understanding the physical meaning behind changing input parameters. As a result, earth scientists are key personnel in running numerical models to get the most appropriate results. Several geoscience courses combine the knowledge of earth sciences with a wide range of computational methods. These courses include Hydrogeology, Advanced Hydrogeology, and Groundwater Modeling.

Examples of state-of-the-art software that are used in teaching these courses and training students at both graduate and undergraduate levels are:

- *GMS* (Ver. 3.1) and *Visual MODFLOW* (Ver. 2.8.2) are user-friendly and widely accepted groundwater flow/transport packages. Both programs help performing calibration, verification, and simulation tasks and output the results on a screen or to a printer. The packages simulate the behavior of groundwater and contamination in the saturated and unsaturated geologic media. Their outputs could be visualized in 2-, or 3-dimensions as shown in Figure 4.

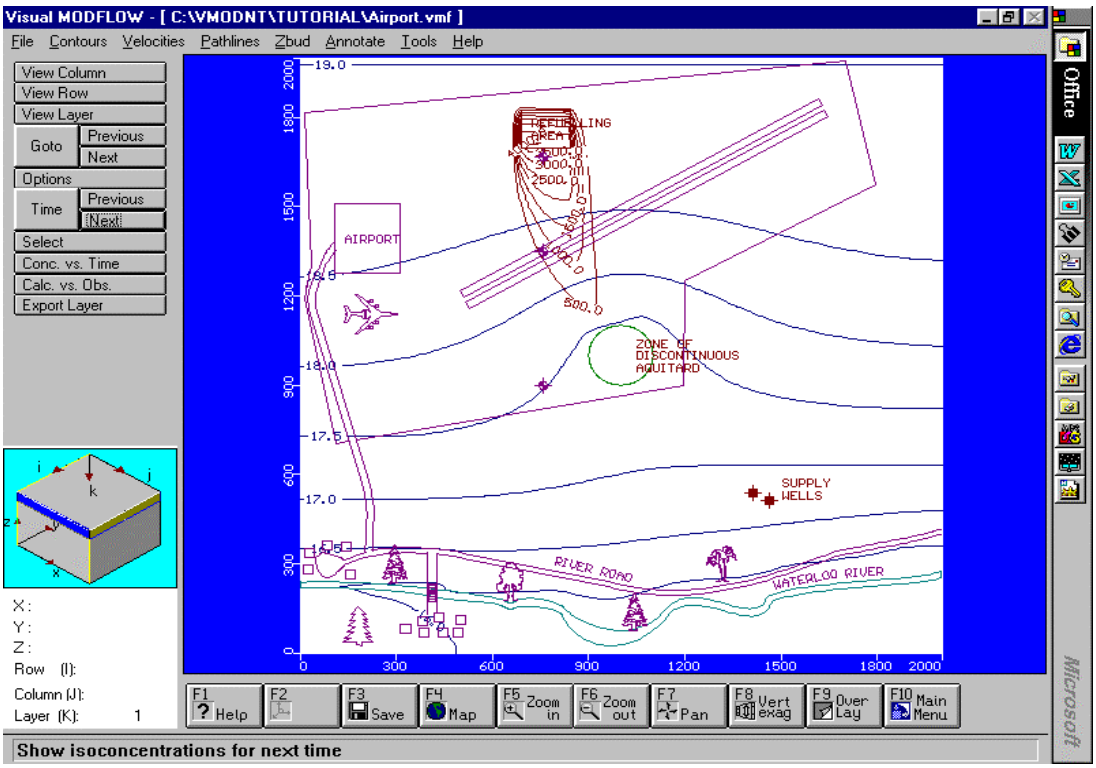

Figure 4. An example from *Visual Modflow* (ver. 2.8.2, 2000) output screen. It shows groundwater head distribution and contaminant transportation mechanism towards the water supply wells

- *VS2DT* (Ver. 2.5) is a software program that simulates complicated groundwater flow and contaminant transport in the vadose zone. It generates different output files that represent moisture content, water saturation and pressure head distribution in either one or two dimensions.

WEB-BASED INSTRUCTION

The use of World Wide Web (WWW) as an instructional tool is gaining momentum as more instructors incorporate it in teaching. Any instruction procedure that makes use of a computer facility is called Computer Based Training (CBT), and those that employ the Web for instructional purposes are known as Web-Based Instruction (WBI). This advance in teaching methods can be employed in a distance education model or as an adjunct to teacher-led classrooms. McCormack and Jones (1998) state that one reason for employing WBI is that "most educators aim to use a teaching method that is effective, efficient, and enjoyable". Web-Based Instruction (WBI) is all of these things.

WBI technology is designed to meet the needs of more diverse student groups. Typical classes consist of students with varying abilities and previous knowledge; therefore, WBI can help teachers to deal with these differences. WBI also allows students to work at their own pace and in a more comfortable learning environment. Some students work faster than their peers while others may wish to take longer time to deliver or prepare an assignment.

From a teacher's perspective, WBI can help in various daily management tasks by reducing the paper flow required for paper-based instruction, allowing for quick and easy revisions to instructional materials, and ensuring that instructional materials are always available to students. An added bonus of Web-Based Instruction is the fact that it can offer students so-called 'virtual teacher' because students can access the instructional materials anytime and anywhere (Butler, 1997a, b, and c). This allows students who were absent the opportunity to access instructional materials away from school, and even the possibility to accommodate students in a course when their schedule is full.

Because this method of instruction allows students to explore concepts in a variety of ways and enables teachers to meet the diverse needs of students in single classrooms, the technique was implemented in ESD to grasp these benefits. An example is the application of WBI to Physical Geology course. An experiment of teaching Physical Geology course using WBI was conducted to evaluate the applicability of this technology for teaching purposes in ESD. Once internet access became available to students at KFUPM and the computer resources of the Department were updated, this facility was used as a complement to this course. Students were prepared for this new teaching practice by introducing the internet, internet browsers, web links, and software required to design websites. One hour of the three laboratory hours is devoted to this purpose.

Course materials were prepared and uploaded to the Server to be available for students through WWW. Students were provided with enough information about the contents of course materials as shown in Figure 5. Therefore, they can link to and explore eight major pages of the site. These pages include Welcome, Course Description, Textbooks, Index to Lectures, Index to Labs, Grading and Exams, Resources, and Class News. Students, usually, spend one hour every week browsing chapter's notes, solving quizzes and exams, and reading other related links worldwide through this site.

After evaluation, it was noticed that the main objectives of this experiment have been achieved. For example, students were exposed to a wide range of information sources via WWW. As a result, this experience helped in enhancing their understanding capabilities and interpretation skills as explained in the subsequent section.

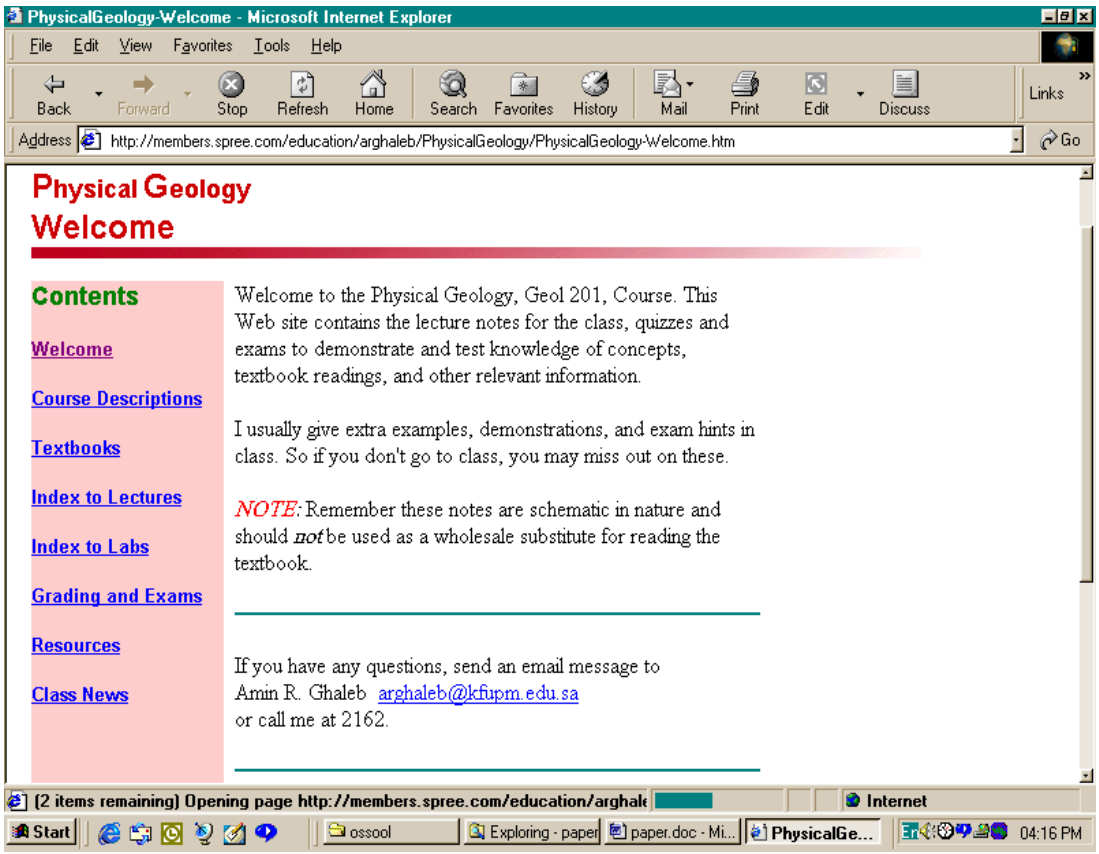

Figure 5. The introductory page of Physical Geology course web site used in Earth Sciences Department of King Fahd University of Petroleum and Minerals (KFUPM) to teach sophomore students

CASE STUDY

A case study was conducted to measure students' reaction about implementing Computer Based training (CBT) techniques in teaching geology courses. A sample of 17 out of 23 ESD undergraduate geology students responded to a questionnaire prepared by the authors for this purpose. The main reasons to seek input from undergraduate students were their new-found experience in dealing with CBT method and more extensive involvement of computer aids and computational methods during their academic life. Students' response was considered a good measure for evaluating computer utilization in teaching. The following academic performance of the sample reflected its fairness:

- 43 per cent of the sample has an overall GPA of 3.0 or above on 4.0 scale,
- 43 per cent of the sample has an overall GPA of 2.0 or above on 4.0 scale,
- 14 per cent of the sample has an overall GPA below 2.0 on 4.0 scale,
- 58 per cent of the sample has a major GPA of 3.0 or above on 4.0 scale,
- 33 per cent of the sample has a major GPA of 2.0 or above on 4.0 scale, and
- 9 per cent of the sample has a major GPA below 2.0 on 4.0 scale.

Half of the sample experienced taking at least one CBT geology course, 19 per cent attended two to three CBT geology courses, and 31 per cent participated in more than four CBT courses. A high percentage of the sample (94%) stated that they benefited from utilizing computer and software in different geology courses because it helps in understanding geologic concepts, solving homework

problems, and interpreting various results. In support of this opinion, 82 per cent of the students indicated that more geology courses should incorporate computer facilities in their curricula to expose learners to new technologies. In response to a question about using Web-Based Instruction (WBI), 76 per cent of the sample stated that they have used the Internet to enhance scientific knowledge. Students explained that the Internet has exposed them to a variety of informational sources and animated illustrations. In addition, it helped in enriching their term papers with recent discoveries and applications. Finally, the complete sample believed that practising use of computer packages and the internet would help them in their future careers because it is the medium of communication and job execution for most employers.

CONCLUSION

Use of the computer became essential and a major part of earth sciences education. Earth sciences courses are categorized into three groups according to the level of computer involvement in their teaching. Courses that use computers in laboratory demonstration, data analysis and problem solving procedures fall in the first group. The second category consists of courses that depend heavily on computational methods like modelling-related subjects. The last group includes courses that use textbook CDs and WBI to explore, illustrate and clarify different geological concepts.

Utilization of computers in geology courses helps both instructors and students to optimally execute classes and build knowledge. Bennett (1996-97) supported this approach by stating, "Although teachers will have to alter their accustomed practices, they will reach a new level of importance, will accomplish more, and will have greater job satisfaction when schools take advantage of the power of computers". He continued by reporting that "computerized education, properly used, can provide a personal side to education that is impossible today". The personal side becomes possible when teachers are released from conventional class preparation and management tasks, which enable them to focus their attention on individuals and diverse groups of students.

Although Earth Sciences is a small department at KFUPM, its pioneering efforts to enhance students' knowledge by utilizing the language of future, computers, are considered a great achievement. It is believed that the Department will continue this endeavor to supply the Kingdom with highly qualified geologists that are not only equipped with conventional geologic skills but also with modern technology.

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APPENDIX A

Undergraduate courses that include computer applications:

- Physical Geology
- Historical Geology
- Mineralogy and Optics
- Structural Geology
- Sedimentation and Stratigraphy
- Petrology
- Petroleum Geology
- Hydrogeology
- Environmental Geology
- Remote Sensing and GIS Applications in Geology
- Geological Mapping Techniques
- Engineering Geology
- Geomorphology
- Computational Methods in Geology

Graduate courses that involve utilization of computers:

- Seismic and Sequence Stratigraphy
- Geophysical Exploration
- GIS Applications in Geology
- Photogeology and Remote Sensing
- Applied Geostatistics
- Geological Lab Techniques
- Advanced Hydrogeology
- Groundwater Modeling
- Development of Groundwater Resources
- Terrain Analysis
- Advanced Engineering Geology
- Geo-Environment