Abstract

Plane surveying has been taught at the University of Melbourne for over 100 years. For the first 80 years the method of instruction was consistently “stand and deliver” lectures and tutor-led practical classes, influenced only by incremental changes in survey technology. The next 15 years saw the introduction of computers and a consequent change in the practice of survey computations that had impact on teaching, but perhaps little influence on learning. Only in the last 5-10 years has there been a new direction in pedagogy that heralds a fundamental change in the teaching and learning of plane surveying. This change has been enabled by the technological advances in computing that have produced the Internet and multimedia presentations, but the changes have been driven by the demands of the university and the expectations of teaching staff and students. This paper describes the planning and implementation of a multimedia development project that takes advantage of the new technology to transform the curriculum delivery of plane surveying at the University of Melbourne.

Introduction

Traditionally plane surveying has been a major component of surveying, land information and geomatics courses, typically positioned in the entry level and second years of the courses. Whilst it is also typical that the entry level also contains curriculum material that is a generic introduction to all aspects of geomatics, the primary introduction to measurement science is based on plane surveying. The material is widely considered as foundation studies that underpin later, specialised material such as geodesy, the cadastre, GIS and mapping.

Plane surveying at the University of Melbourne is taught to approximately 300 undergraduate students in entry level geomatics courses and service courses. There are eight units with full or part curriculum devoted to plane surveying taught across five discipline areas, namely geomatics, civil engineering, building, forestry and archaeology. The five separate subject streams which deal with plane surveying in whole or in part are currently taught as conventional three or six hour per week units, with lectures on plane surveying principles and mathematical processes, tutorials on calculation practice, and field work on measurement acquisition with surveying instruments.

In common with many geomatics programs at tertiary level, the proportion of the course devoted to measurement science, including plane surveying, has been shrinking in response to a number of factors (Williamson and Ogleby, 1999). The first of these is pressure on the number of contact hours in engineering and science courses due to the wide perception of “over-teaching”, which leaves little time for students to engage in elective studies and a more general education at university level. The second factor is the proliferation of combined degree courses, allowing students to graduate after five or six years with two degrees that, when taken separately, would require three to five years each. Although there is commonly some overlap of material between closely aligned disciplines, inevitably some geomatics material is removed from the combined degree programs due to the pressure of time. The third primary factor is the change in emphasis in geomatics courses, such as the course at University of Melbourne, moving away from the more technical skills associated with plane surveying toward higher level design and planning expertise associated with GPS, GIS and land management (Trinder and Han, 1999).

Service courses taught to other disciplines are not immune to this pressure, and have also reduced the amount of material on plane surveying. The teaching of plane surveying has had to be adapted to the reduced time available, concentrating on the more common tasks and re-orienting the material toward design and analysis, rather than the mechanical skills of field surveying.
The Learning Problem

In concert with the contraction of the time available for plane surveying material in courses, it is widely accepted that there is a learning problem associated with plane surveying. Unlike many of areas of tertiary education, plane surveying is a relatively sudden acquisition of new knowledge and new practical skills due to unfamiliarity with the basic concepts of surveying and positioning. Whilst students entering classic disciplines such as medicine, law or economics have some understanding of the fundamentals, this is generally not true of students entering geomatics, surveying or land information courses. The required synthesis of new knowledge and new skills, combined with the management and operation of complex survey equipment in the field and the design and operation of field surveys, is often overwhelming for inexperienced students. In this environment the educational objectives can become completely obscured by the overload and the student does not learn the essential concepts of plane surveying measurement.

Further, a continuing difficulty with teaching plane surveying measurement at entry level in tertiary education is maintaining a clear connection between the mathematical processes, the surveying equipment and the field work techniques, whilst accommodating a variety of practical skill abilities and differing cultural backgrounds of students. At the University of Melbourne, the variety of student cohorts, and the associated different levels of mathematical skills, is a significant issue because plane surveying is taught as core material to students in the geomatics programs, and as service courses to students in engineering, science and humanities courses. Students with relatively poor preparation in basic mathematics are clearly disadvantaged, and inevitably have much greater difficulty understanding design concepts that are based on principles derived from geometry and statistical theory. Similarly, cultural differences often result in differing aptitudes for field survey work, and students can also be disadvantaged by the intimidation of taking responsibility for and handling expensive equipment such as total stations.

A New Pedagogy

A potential solution to the combined problems of providing quality teaching over shorter time frames, and overcoming learning problems associated with poor synthesis of concepts and skills, is a dramatic change to the pedagogy of teaching plane surveying. Rather than teach the basic skills of plane surveying (the bottom-up approach) which must be integrated to provide optimal learning outcomes, the teaching method can be changed to the challenge of problem solving (the top-down approach) with the emphasis on deep learning of design and analysis. This new approach has to be supported by a rich resource that provides the details of field procedures and theoretical concepts. A problem based approach concentrates on design and analysis in lectures, de-emphasising issues such as the fine detail of instrument handling and field procedures.

The outcome of this revised approach to the teaching of plane surveying should be a change in the students knowledge acquisition from a rote learning attitude to a problem solving approach, based on a more thorough understanding of the concepts of plane surveying algorithms, techniques and field procedures. This change in pedagogy requires a change in the culture of learning by the students, and delivery by academic staff; and is facilitated through an integrated approach provided by multimedia material that continually emphasises the links between geometry, measurement and instrument handling. The provision of a rich resource of educational material on the basic concepts of plane surveying also allows academic staff the possibility of using more of the available teaching time to address individual learning needs of students on the higher level processes of measurement problems.

A vital component of the new pedagogy is demonstration of the field procedures through simulations and animations, in order to minimise the intimidating effects of complex instruments and complicated field procedures. The benefits of simulated field work and site visits has been demonstrated for both spatial science (Moore, 1997) and other disciplines (Russ and Wetherelt, 1999). When presented with a field measurement problem, the outcome should be that the students will focus on the solution to the problem in terms of plane surveying techniques, rather than being absorbed by acquiring the physiological skills of measurement processes with surveying instruments. Multimedia delivery of the curriculum material should also facilitate and encourage independent learning by students, which is often discouraged by “stand and deliver” methods. The availability of and encouragement to use
online interactive material gives students feedback on their knowledge acquisition outside of formal contact with lecturing and tutorial staff during class times.

A disadvantage of this approach is that students have less time cultivating practical skills and therefore have less general experience with field surveys and handling of instruments. There are a number of arguments to counter this perceived deficiency in the skills of new graduates. Perhaps the most compelling is that no matter how much field practice is included as a component of a geomatics course, new graduates who become field surveyors learn or re-learn many of their skills on the job. Plane surveying is always taught in the early years of the course as foundation material and there is often a delay of two to three years before new graduates practice their skills. In addition, many survey organisations have idiosyncratic procedures for field surveys or are required to adhere to local or regional regulations, and this factor is more likely because of the larger proportion of graduates seeking employment overseas.

The second response is that many graduates of tertiary programs will never practice as field surveyors. An increasing number of graduates are moving and will move into information systems or project management, so their need for the skills associated with plane surveying is at a project or data management level rather than at a practical level. Students entering geomatics courses have high expectations of their degree programs, and international and fee paying students in particular perceive a tertiary level geomatics degree as a springboard into information systems or project management careers.

Curriculum Transformation

Web Site Project

In 1998 the Department of Geomatics embarked on a project to address the teaching and learning objectives outlined above, using financial support from an internal grant from the university and in-kind support from the department. The project aimed to transform the entire conventional delivery of common material on plane surveying into a multimedia based, online curriculum for self-paced learning and assessment. A project team was formed, comprising academics for content delivery, a web designer/programmer to develop the web site, and a Java programmer to program the problem simulations.

![Figure 1. Problem based presentation of material by the web site.](image-url)
The project team has completed the first phase of a transformation of the curriculum delivery of plane surveying. The web site has been created (see figure 1) and combines a rich resource of theory material, an equipment database, animations of essential field procedures and, most importantly, simulations of real world survey problems that provide immediate feedback. The theory material and equipment database are straightforward web pages written in HTML. The animations were created by Macromedia Director and stored within the web pages as Shockwave applets. The problem simulations were written in Java as separate modules and are linked to the web pages. The problem simulations are supported by a survey analysis tool to process simulated field surveys and produce feedback in the form of location results and the precisions of computed locations. The survey analysis tool is based on a survey network adjustment program (Shortis and Seager, 1994) which is provided with correctly formatted data by the problem simulations. The advantage of the survey network adjustment program is that it can process virtually any data set and individually tailored solutions are not required.

The initial project design included a number of video sequences to illustrate field procedures, but these were dropped, in favour of animations, during the development of the site. The recording, editing and conversion of video sequences could not be accommodated within the budget for the project if they were to be professionally produced. Production of the sequences using the resources available within the project team was feasible and the realism of video sequences was attractive in order to illustrate field procedures, however Director/Shockwave animations proved to be very effective at conveying the concepts associated with field procedures and animations are not affected by the “clutter” associated with real video.

The structure of the web site is shown in figure 2. The site is split across two servers, one provided by central computer services and one supplied by the department. The “WebRAFT” Unix server provided by central computer services restricts the access to authorised users only via an authentication system linked to a student information database. The advantage of this is that only legitimate students enrolled in relevant subjects gain access to the web site and it therefore protects the intellectual property of the university and the Melbourne Zoological Gardens. The current version of WebRAFT provides only a delivery mechanism for HTML pages and browser plug-ins, so the higher functionality required by Java problem simulations and the survey analysis tool had to be provided by the department, using a separate Unix server. These links are quite transparent to the user.

The design of the web site is oriented around the metaphor of survey problems within the Melbourne Zoological Gardens (see figure 1). The use of the zoo environment was adopted for a number of reasons, but principally because the site was being used for field survey work as part of the teaching program for the geomatics courses. The zoo had proven to be a particularly challenging environment due to the issues associated with dealing with zoo management, interacting with zoo keepers and conducting surveys in a public place. In terms of the presentation of the online resource material, a zoo is a familiar environment for the vast majority of students and has the potential to create or adapt a variety of realistic plane surveying problems. In contrast, a construction site, for example, could
pose a number of real survey problems, but the nature of the work is limited by the available variety of circumstances. Although no metaphor is perfect and no particular type of site provide can provide a complete range of surveying problems in a totally realistic fashion, the zoo site was selected as a reasonable compromise between familiarity, convenience, realism and adaptability.

Problem Simulations

The presentation of problems is in accord with the problem based, top-down approach that encourages students to be aware of the context in which plane surveying work is carried out. Students are presented with a logical sequence of measurement problems of increasing complexity and are guided, through appropriate feedback, to feasible solutions. Once selected, a particular field survey measurement problem is introduced by a problem brief that outlines the environment, circumstance and the problem to be resolved (see figure 3). Included in the brief is a measurement precision specification, generated randomly for a finite list of possibilities, that must be achieved.

Figure 3. Example explanatory page from a problem brief.

Figure 4. Example feedback page from a key word entry into a problem brief.
Through a logical sequence of elimination of procedures, the problem brief channels the student to a feasible solution to the survey problem. In some cases the possible survey techniques are refined by accuracy and reliability considerations, whilst in other cases purely practical considerations may rule out a particular technique.

The selection of the appropriate survey technique is reinforced by feedback from the students, required as part of the sequence of web pages presenting the problem (see figure 4). Questions range from simple selections from multiple choices, selections that can have correct, neutral or incorrect returns, and entry of key words that are linked to major and minor issues. All responses to questions are illustrated by text explanations of the correctness or otherwise of the choices. Students are also required to select appropriate survey instruments to use in the field to solve the problem at hand. Again, feedback through text explanations is used to illustrate the correct and incorrect choices.

Once reached, the problem simulation is launched (see figure 5) and a help page can be opened as a separate browser window to allow a clear explanation of the operation of the simulation. The student is then required to place survey stations and measured positions to solve the problem. Actions by the user are governed by tool selections, which may be survey instruments, survey station placement, measurement deletion or auxiliary information such as break lines in a contour and detail survey.

![Figure 5. Example problem simulation showing feedback from error ellipses.](image)

In every case there is a calculation process that illustrates the precision of the positions located using error ellipses. This provides direct feedback to the student for an analysis of their survey design, as well as an indication as to whether their survey has reached the required precision specifications. Using their knowledge of geometry and propagation of variance, through simple trial and error, or from a combination of both, the student can refine their design to achieve an acceptable result. Factors such as gaining near-isotropic error ellipses and the appropriate selection of field equipment can be evaluated within the problem simulation to encourage the assimilation and reinforcement of survey design skills by the students. If a deep understanding of survey design skills can be engendered in the students, actual field surveys should be less troublesome and logistical issues should be less likely to obscure the learning objectives.

**Other Web Site Features**

The web site has a quite deliberate problem based orientation, but there are other features that may be accessed directly by students using the tool bar at the top of all HTML pages (see figures 1, 3, 4, 6 and 7). The usual help and information pages are present, as well as a glossary of terms and a comprehensive list of mathematical symbols, concepts and formulae. The latter opens in a separate window that can be maintained on the screen at all times (see figure 7). Also included is a “map store” that contains aerial photographs and pre-existing maps of the site.
The remaining major features of the web site are the theory pages and the equipment database (see figure 6). The theory pages are organised by topic and contain text and graphic information on the background, methods, data recording and reduction for plane surveying tasks. In many cases the survey procedures and data reductions are illustrated by Shockwave animations. The equipment database contains information on a large range of equipment used for plane surveying and has many links to the glossary of terms and the animations of survey procedures (see figure 7). For the most common types of equipment there is also information on calibration, precision and accuracy, factors influencing measurements and common measurement tasks, as well as animated diagrams of instrument components and controls. The theory and database pages constitute what is commonly referred to as an electronic textbook, although this tag is not totally appropriate due to the presence of the many animations of survey instruments, procedures and data reductions. Animations of survey instruments have been and are being used in plane surveying as stand-alone tutorials (Kniest, 1997).

Figure 6. Equipment database entry page.

Figure 7. Survey procedure animation example and fundamental formula window.
Evaluation

The initial design of the multimedia material and the educational process was reviewed by academics, current undergraduate students, postgraduate students and practising surveyors. Plane surveying is a fundamental component of the discipline and any academic or professional practitioner can evaluate the content and emphasis of the material. As expected, the initial design was an iterative process as the ideas, concepts and procedures were developed and refined. Additional evaluation of the initial proposal was afforded by an external review of the Department of Geomatics in early 1998. The three professors taking part in the review were all involved directly in curriculum revision and indirectly in innovative teaching practices in geomatics at their respective universities. The independent advice and input of these experienced academics and the other evaluations were valuable in confirming that the project proposal was a valid and feasible approach to the teaching and learning of plane surveying.

During April-May 1999 the web site was subjected to a formative evaluation by four teams of two students, comprising later year students in geomatics or combined degree programs, and postgraduate students who had completed geomatics or combined degrees. The evaluators were given directed tasks to review the theory, animations and problem simulations, and then fill out feedback response forms. The major issues from the list of suggested changes to the site were implemented. The principal changes made related to navigation within the pages, additions to the equipment database, and the help, use and visualisation of the problem simulations. In general, the reaction to the web site from the students was very positive, with a recurrent theme that the students felt that access to such a site during the early years of the geomatics programs would have been very beneficial.

However, the later year and postgraduate students were volunteers, and it is widely accepted that such evaluations tend to be biased toward positive results because the students are self-selecting toward those who appreciate computer-based learning and information technology in general. The web site was extensively used in lectures and tutorials for the first time in mid and late 1999. The general reaction of entry level students in geomatics courses was much less positive, as monitored by the academic staff involved in the teaching of plane surveying. The most apt description of the response to the use of the web pages is “mixed”.

Many of the negative reactions were generated by very practical issues, such as the contradictory formatting and design requirements for screen display and printing of web pages. The plane surveying web site is specifically designed for screen display, as this was the intended use. Despite the issue to students of printed notes covering the theory aspects of the curriculum, many students attempted to print large sections of the web site, leading to frustration with the output of many individual web pages not compatible with the printed page. Students also complained, with some justification, that the lecture notes and the web pages were sometimes inconsistent and animations could not be viewed in any other medium.

Anecdotal evidence suggests that the negative comments are related to previous experience with the predominant culture of teaching and learning at secondary level. Students from backgrounds that contain little computer based learning are constrained by a narrow concept of tertiary education and a tradition of passive learning, leading to a significant culture shock. Students from a secondary education with a greater component of active learning, using computer based techniques, are more prone to accept the use of the web site and online delivery. In many cases students were very positive about the animations and problem simulations, as well as the availability of self-paced review and reflection on the concepts of plane surveying.

Further evaluations will be conducted in the future. The web site is being used once more for the delivery of plane surveying in the geomatics courses at entry level in 2000. The evaluations will be based on informal and formal student feedback. Use of the web site, animations and problem simulations are continually monitored by academic staff during tutorials and practical classes in computer laboratories. More formal feedback from student evaluations and focus groups will be carried out toward the end of the second semester in 2000.

There is relatively little scope for summative feedback based on quantitative data. As is the case with almost all curriculum transformations, “before and after” comparisons are rendered invalid by the
many confounding factors associated with introducing new teaching methods, as well as the lack of evaluation data from previous years. Not only has the curriculum changed during the introduction of the problem based learning, but also the student cohorts are often dissimilar. Although entry scores are an unreliable guide to student achievement, there is enough variation to indicate that, in the absence of some method of calibration of the ability levels of student groups, comparison of examination results would be quite misleading. Detractors of curriculum transformation and multimedia techniques often cite the lack of hard evidence of improvement as a failure of these methods to improve teaching and learning. This argument is not easily refuted and the lack of acceptable measures of improvement in student learning is an impediment to wider adoption of curriculum transformation and computer based delivery.

Further Development

The plane surveying site is now effectively in “maintenance” mode. Through a combination of review by academic users and feedback from students, amendments and minor additions will be made to continually improve the web site. Not all of the envisaged problem simulations have been developed due to the budget and time constraints of the initial project work, and additional problem simulations will be added if feasible.

The initial project design also included a series of case studies, intended to reinforce the problem simulations by providing exemplars of good survey design. Finally, there remains some justification for the inclusion of video sequences to illustrate field procedures with the ultimate in possible realism. Like the case studies, video sequences will be selectively added if resources can be found to design, develop and implement the additional material.

The design concept of problem based approach and the development of the web site is only the first phase of the curriculum transformation. The second phase of the transformation is the full integration of the problem based learning into the core and service teaching of plane surveying. As noted previously, this requires acceptance of the techniques by academic staff, as well as a change in the culture of learning by students and a change in the culture of teaching by academics. The emphasis must shift from project development to ownership of the new techniques and the routine use of online delivery by staff and students.

Conclusions

In summary, the multimedia material provides a rich resource of information and simulation of survey design, measurement fundamentals, use of instruments and field procedures. The presentation of comprehensive simulations of the field work processes, including instrument handling, prior to the students taking equipment into the field will lead to more efficient use of the equipment. Efficient operations in the field will enable the students to concentrate on the correct implementation of measurement processes, rather than contending with the lack of essential skills in equipment use. The multimedia material will reiterate and augment the principles of measurement presented in formal lectures, utilising the dual mechanisms of presenting simulations in lectures and self-paced review by students. As a consequence of the student use of the multimedia material, tutorials should be able to concentrate more on the higher decision making processes associated with plane surveying measurement, rather than drilling students in basic concepts.

The top-down approach of problem simulations should allow students to investigate the design and practice of field surveys at their own pace, before attempting these procedures in the field. Further, the self-paced learning process should also allow those students with weaker backgrounds in geometry and trigonometry to explore or re-acquaint themselves with the basic mathematics of plane surveying, provided contextually within the material. Finally, the use of self-paced multimedia support allows the more capable students to proceed to more advanced material and concepts with a minimum of supervision, allowing the concentration of tutorial and demonstrator effort towards the students whose need is greatest. In time, the acceptance by staff and students of the transformation of the teaching and learning of plane surveying should provide a deeper appreciation of the design and analysis of surveys, whilst still imparting sufficient knowledge and appreciation of basic procedures and practice of field surveys.
References


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Contact Information

Department of Geomatics
University of Melbourne
Victoria 3010, AUSTRALIA

Tel : +61 3 8344 6806
Fax : +61 3 9347 2916
Email : {m.shortis|c.ogleby|a.kealy}@eng.unimelb.edu.au