WEB-BASED LEARNING OF SPATIAL DESIGN AND ANALYSIS CONCEPTS USING SIMULATIONS AND VISUAL FEEDBACK

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ABSTRACT

This paper describes the process and results of the transformation of the curriculum delivery of four different areas of the syllabus of the geomatics programs at the University of Melbourne. In each case the transformation addresses the teaching and learning problems associated with spatial relationships in two or three dimensions by providing a rich resource of theory material, animations of spatial concepts and, most importantly, visualisations or simulations of real world survey problems that provide immediate feedback. The visualisations and simulations allow students to investigate the design and analysis of spatial geometry and spatial relationships at their own pace, using the feedback to reinforce their learning. The online material affords an enhancement of the learning experience for undergraduate students, both complementing and providing an alternative to the conventional teaching methods of lectures, tutorials and practice classes.

INTRODUCTION

Measurement science has always been a major component of surveying, spatial information and geomatics courses, and is typically taught across all years of the courses. At the University of Melbourne, entry level measurement science contains curriculum material that is a generic introduction to all aspects of geomatics, whilst material presented in later years becomes increasingly specialised in sub-disciplines such as advanced plane surveying, geodesy, the cadastral, GIS and mapping. The majority of subjects are taught as conventional three or six hour per week units, with lectures on 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 has been shrinking in response to a number of factors. 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, that allow 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 program 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 measurement science toward higher level design and planning expertise associated with GPS, GIS and land management.

The Learning Problem

In concert with the contraction of the time available for measurement science material in courses, it is widely accepted that there is a learning problem associated

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with the spatial relationships embodied in measurement science. Unlike many of areas of tertiary education, measurement science 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 frequently not true of students entering geomatics, surveying or spatial information courses.

At entry level, students need to understand the geometry of and error propagation associated with, for example, surveys for large-scale mapping. At the advanced plane surveying level, students move on to the more demanding learning task of understanding survey network design, computations and analysis in three dimensional space. Typically students then progress to higher concepts of geodesy and GPS based on the ellipsoidal shape of the earth. 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 measurement science.

Further, a continuing difficulty with teaching measurement science 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 as measurement science 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 and GPS receivers.

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 measurement science. Rather than teach the basic skills (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 or case studies (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 of online educational material that provides the details of field procedures and theoretical concepts. A problem based, project based or case study approach concentrates on design and analysis in lectures, de-emphasising issues such as the fine detail of instrument handling and field procedures.

Problem based and case study approaches have proven to be effective in many disciplines such as engineering [1, 2, 3], medicine [4] and economics [5]. The use of visualisations and simulations for teaching and learning is widespread, and simulated site visits often have a spatial nature, such as uses in architecture [6], mining [7] and
The outcome of this revised approach to the teaching of measurement science 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 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 measurement science 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 spatial relationships and field procedures through simulations and animations in order to minimise the intimidating effects of complex survey designs and complicated field procedures. When presented with a field measurement problem, the outcome will be that the students will focus on the solution to the problem in terms of 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.

The widely recognised difficulties with the introduction of a student-centric approach to learning are transition problems and cultural inertia. The first use of problem based or case study approaches requires a revision of the curriculum and increases the dependence of the teaching staff and students on web based material. Alterations to a curriculum and the web site always require some fine tuning during the first time the new material is used. Changing the culture of teaching and learning can be extremely difficult. Students who come from a traditional teaching environment at secondary school, and have traditional teaching methods in other subjects in the same course, may find it difficult to adapt to isolated subjects that have adopted a very different approach to learning. Teaching staff may be subject to a high initial load to change the culture, and then may be required to teach in very different modes for different subjects. However, none of these difficulties is insurmountable and there are clear benefits in the introduction of problem based or case study approaches, based on evaluations of student satisfaction with their own learning and improved academic performance [3, 5, 10].

Further, a discipline-specific 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. The second response is that many graduates of tertiary programs will never practice as field surveyors and typically will move into information systems or geography [8]. Further examples of multimedia education resources, with an emphasis on the spatial sciences, are given in [9].
project management, so their need for the skills associated with measurement science is at a management level rather than practical level in any case.

FOUR MULTIMEDIA DEVELOPMENT PROJECTS

Each of the four projects described in the next sections are based around web sites that have been created to provide simulations or visualisations of spatial problems as a primary function. The spatial concepts are presented either as simulations of real world survey problems or visualisations of spatial relationships. In addition, some of the projects also include an equipment database, detailed simulations of survey equipment and animations of essential field procedures. All projects provide access to theory and practice material, such as lecture notes, tutorial guides and example data sets.

In all cases the theory material and equipment databases are straightforward web pages coded in HTML. The animations have been created by Macromedia Director and stored within the web pages as Shockwave applets. Visualisations are presented as VRML models [11] or rotating images, viewed using browser plug-ins such as CosmoPlayer [12] or Zoom Viewer [13]. Some of the visualisations and animations of field survey procedures required the use of CAD software to create the models and then generate image sequences that were exported to Director, or converted directly to VRML models. The problem simulations are coded in Java as separate modules and are linked to the web pages, or coded in C++ and loaded as a browser plug-in. The problem simulations are supported by a survey analysis tool that processes simulated or actual field surveys and produces 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 [14] that 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.

In all four cases the multimedia material is or will be tightly integrated into the relevant courses. The web sites are used within lectures and tutorials to illustrate problems and theoretical material. Further, all subjects make use of tutorial and practical assignments, and many assignment tasks are oriented around the problems and visualisations included in the multimedia material. In some cases the students’ solutions to the problem simulations are submitted as part of the assignment report.

Plane Surveying Concepts and Field Procedures

This 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. Plane surveying 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. Through a problem-based approach, the principal aim of this project is to allow students to familiarise themselves with plane surveying equipment and field procedures before they attempt surveys in the field.
Select A Problem

1. Provide A Control Survey
2. Map The Layout Of The Seal Pool
3. Contours Inside The Lion Cage
4. Drainage Gradient Of The North Lawn
5. Relocate A Control Point
6. Height Of The Flight Aviary
7. Alignment Of A Rainforest Path
8. Set Out Some New Cage Foundations
9. Area Of The Elephant Enclosure
10. Map Plants In The Butterfly House

The Plane Surveying site contains a number of surveying problems based upon the environment of the Royal Melbourne Zoological Gardens. Each highlighted area of the map of the Zoo shown above has a different surveying problem for you to solve.

The photograph in the top left corner of the map is an aerial photograph of the zoo. Click on this image if you wish to see a larger version of this image.

Figure 1. Problem based presentation of material by the web site.

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 previously being used for field survey work as part of the teaching program for the geomatics courses. 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.

For the purposes of this problem solving exercise you will be measuring the area shown outlined on the image above, rather than following the exact curve of the existing wall.

Points A and B are control points from an existing control survey. There are other control points on the exterior of the enclosure which will be shown later in the problem but which appear outside the bounds of this image.

Figure 2. Example explanatory page from a problem brief.
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. Once selected, a particular field survey measurement task is introduced by a problem brief that outlines the environment, circumstance and the problem to be resolved (see Figure 2). 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 3). 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 2D problem simulation is launched (see Figure 4) 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 acquisition, measurement deletion or auxiliary information such as break lines in a contour and detail survey. Immediate feedback is provided by the error ellipses, to optimise the design of the survey, and the numerical data, to determine whether the survey is meeting required specifications. The plane surveying site has been used in the geomatics courses and service units since 1999. More detail on this project, including information on evaluation of the web site, is given in [15].

Figure 3. Example feedback page using drag and drop in a problem brief.
Learning Design of Survey Networks

One of the fundamentals of the execution of field surveys is the effective and efficient design of survey networks. This combination of knowledge and design skill underlies much survey work, and is a strategic area of teaching for tertiary courses in surveying and geomatics. An effective method of learning design skills is to expose students to a series of case studies and problems within a realistic environment that provides interactive guidance on the efficiency and effectiveness of the survey network design. Networks can be designed by identifying station locations and measurements within a 3D virtual landscape, and real-time feedback on design outcomes is generated by the survey network analysis tool. Guidance on the design effectiveness is provided using error ellipsoids that can be used to identify weak areas in the survey network, and reliability and precision data that can be compared to appropriate design specifications. Assessment of efficiency, in terms of time in the field to complete the survey, is currently a manual inspection process that may be automated in the future.

The web site uses the metaphor of a survey instrument console to provide a familiar "look and feel" and a very consistent and straightforward approach to using the site, based on two levels of navigation buttons (Figures 5). The site includes many interactive animations illustrating theoretical concepts and field survey procedures. Other animations demonstrate the relationship between typical survey measurement geometries and the resultant station location precisions (Figure 5). In all cases the relationships are presented in the context of a real world problem, and the precision information is shown as error ellipses (2D) or ellipsoids (3D). The relative sizes and the shapes of error ellipses are a universal mechanism used to evaluate the global uniformity and local strength of survey networks.
The problem oriented approach to the design of survey networks is encapsulated in the concept of survey projects. Again, this is in accord with the nature of survey instrumentation, such as GPS navigators, that tend to categorise data storage in terms of projects. The design of the web site incorporates a survey network simulator and a separate model viewer, indicated by "Open Project" and "View Project" respectively in terms of the console. The latter was included (see Figure 6) to allow students to browse VRML models of survey network case studies using any plug-in viewer so that they could explore the virtual models in "read only" mode from any computer with a network connection.

The OpenProject mode of operation (see Figure 7) is the most important component of the web site and is based on a plug-in developed to allow interaction between the user and the VRML model of the terrain and survey. The TerrainVis plug-in allows the user to:

- Navigate around the VRML model.
- Import and export files of survey station and measurement data.
- Occupy and sight to specific survey stations in the network.
- Add new survey stations and add or delete survey measurements.
- Compute the survey network solution in measurement or simulation modes.
- Display feedback from the survey analysis tool including error messages and error ellipsoids.

As part of the tutorial exercises associated with the course work, students are required to carry out an analysis of a dam deformation survey (see Figure 6) and use the simulator to design a building monitoring survey (see Figure 7). Although the use of the simulator cannot and was not intended to replace actual field surveys, it does allow students to practice their design and analysis skills. The survey networks site has been
used in the geomatics courses since 2000. More detail on this project, including information on student use and evaluation of the web site, is given in [16].

Figure 6. Dam surveillance model viewed using CosmoPlayer.

Figure 7. Building model viewed using the TerrainVis plug-in.
Visualisation of Navigation and Positioning Problems

Students in the geomatics degree programs are required to have a fundamental understanding of navigation and positioning, both on and beneath the Earth’s surface. The concepts associated with spatial relationships within a 3D world, and the ability to describe these relationships, are a common thread in the sub-disciplines of surveying, geodesy and mapping. A problem that is frequently encountered when discussing navigation and positioning is the inability of students to visualise the 3D spatial relationships. Conventional diagrams and figures represent these 3D relationships as a series of 2D views which often require a great deal of elaboration in order to explain the representation. The 2D views can often be very complex if the mathematical abstraction and the real world problem are to be shown in context with one another.

One solution to this learning difficulty is to present 3D navigation and positioning problems as 3D simulations that are realistic, layered and animated. Realistic VRML models can present 3D spatial relationships very clearly and the ability to rotate the models is critical, as interpreting the 3D geometry from apparent motion around the object is very often pivotal to students’ ability to analyse the spatial relationships between vectors and surfaces. Scenarios can be created for many fundamental spatial relationship problems in surveying, geodesy and mapping. The impact of the visualisation and animation is much more critical for subtle and complex problems, such as the various definitions of 3D vector intersections and the shape characteristics of geodesics on the ellipsoidal Earth.

The web site created for the navigation and positioning project again presents the visualisations in the context of real world scenarios (Figure 8). The six examples included or under development cover vectors in 3D space, vectors and lines, vectors and planes, vector intersections, spherical trigonometry and line intersections on the ellipsoidal Earth. Each scenario contains a tutorial that steps the student through the spatial relationships, a number of 3D models and images that can be viewed using plug-ins, a linked spreadsheet exercise and a spreadsheet template for the exercise (Figure 8).

Figure 8. An example of the scenario components in the navigation and positioning site.
Each scenario includes a Zoom Viewer display (Figure 9) for “constrained” investigation of the spatial relationships and a VRML model (Figure 10) for “free” investigation of the spatial relationships. The Zoom Viewer model allows students to rotate the object about one axis to allow an important view aspect to be presented. The VRML of the 3D object allows complete freedom of movement around and within the model. It is easy to get spatially or intellectually "lost" within the 3D model, so in each case pre-defined views are provided to illustrate the most important aspects of the geometry.

![Figure 9. Zoom Viewer model of spherical trigonometry.](image)

The scenarios are once more strongly integrated into the course work for the undergraduate students, as the tutorial exercises are an assessed component of the course. The web site was used for the first time in 2001 and initial feedback from the students was very positive. In particular the students found that the flexible access to the tutorials and models very useful in understanding the spatial relationships.

![Figure 10. Views of the VRML model of vector intersection.](image)

**Integrated Systems in Geomatics**

Integrated Systems in Geomatics was introduced into the final year of the undergraduate programs in 2001. The subject was developed to consolidate the practical and theoretical information covered in earlier year subjects. It is often the case that the material introduced to students in Geomatic Engineering is taught as distinct, almost separate subject areas. Integrated Systems in Geomatics is aimed at
presenting the methods and concepts through which these diverse subject areas can be integrated to develop solutions to real world problems.

The newest multimedia project supports this subject by preparing students to use GPS technology in the field and to provide students with virtual experience of the measurement processes and technology of integrated systems. Students are able to visualise the limitations and capabilities of different data acquisition techniques and the different methodologies that can be combined into feasible solutions for contemporary measurement problems. Integration is demonstrated using case studies and is pivotal to the understanding of design and analysis of positioning and navigation systems.

The development of the curriculum for Integrated Systems was significantly hampered by the lack of adequate reference texts, as well as an increasing inability of the university to provide adequate access to sophisticated and modern instrumentation. Both of these issues are typical problems for any subject where developments in technology are rapid and ongoing. Tertiary education institutions inevitably have restrictions on the resources that can be made available to teaching programs, and the provision of a broad range of current texts and state of the art field survey equipment is often not feasible.

The provision of online resources will never completely eliminate the need for reference material, but it can ameliorate a deficiency and so a series of modules have been developed to provide the necessary theory for the subject. Feedback from students has indicated that they found this information to be an important learning tool, as it supplemented the lecture material without significant duplications. It filled a gap that would ordinarily have been occupied by reference texts. The use of three-dimensional models and animations presented the material in a more informative fashion where students could readily visualise the associated three-dimensional theory.

Regarding equipment, it is often the case that a small number of geodetic class GPS receivers, for example, must be shared amongst a large number of students. Virtual access to equipment is not a replacement for actual experience, however virtual access is better than no access, and a simulated GPS receiver does allow students to have some preparation and familiarity with field equipment and therefore make efficient use of the equipment when it is available. Use of virtual equipment becomes an essential enhancement of the student learning process to facilitate very effective access to real equipment.

Accordingly, the main components of the web site are:

- A series of local case studies that illustrate the range of measurement solutions provided by integration of technologies such as GPS, GIS, remote sensing and conventional surveying (see Figure 11).
- A comprehensive and detailed tutorial on GPS technology, including animations of GPS survey methodologies and a simulated geodetic GPS receiver (Figure 12).
- A Java utility for the conversion and transformation of geodetic coordinates and datums.
- Links to other resources such as GPS mission planning, reduction and analysis software.
The case studies are used as an assessed component of coursework and are presented as a tender situation in which student teams present a proposed solution to the client.
The student response to the tender indicates the team skills and integrated systems approach to accomplishing the task, including project management and costings. Components of the web site were first used in 2001 and the first comprehensive use of the web site occurred in semester 2, 2002.

**EVALUATION**

In general, the initial design of the multimedia material and the educational process has been reviewed by academics, current undergraduate students, postgraduate students and practising surveyors. All of the four projects are fundamental components of the discipline and any academic or professional practitioner can evaluate the content and emphasis of the material. As could be expected, the initial designs are an iterative process as the ideas, concepts and procedures are developed and refined. In most cases the web sites have then been subjected to a formative evaluation by teams of students, comprising later year students in geomatics or combined degree programs, or postgraduate students who had completed geomatics or combined degrees. The evaluators are given directed tasks to review the theory, animations and problem simulations or visualisations, and then fill out feedback response forms. The major issues from the responses to the use of the sites are implemented, and typically relate to navigation within the pages, additions to the background information or equipment database, and the use and visualisation of the problem simulations. In general, the reaction to the web sites from the students has been very positive, with a recurrent theme that the students felt that access to such a site during the geomatic programs would have been very beneficial.

However, the later year and postgraduate students are 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. All four web sites have been used in lectures and tutorials, and the general reaction of undergraduate students in geomatics courses was less positive, as monitored by the academic staff involved in the teaching.

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 web sites are specifically designed for screen display, as this was the intended use. Despite the issue to students of printed notes or online PDF documents covering the theory aspects of the curriculum, many students attempt to print large sections of the web sites, leading to frustration with the output of many individual web pages not compatible with the printed page. Students also regularly complain, with some justification, that the lecture notes and the web pages are sometimes inconsistent and animations could not be viewed in any other medium. Another common response concerned the provision of “model” answers. Whilst this is somewhat independent of the medium of delivery, there is at least some justification to the request for model answers and example solutions in order to guide the students. The clear disadvantage of providing such information is that it tends to discourage self-learning and reduces the effectiveness of problem based and case study learning.

From anecdotal feedback from students, both positive and negative reactions were also generated by cross-subject use of the multimedia modules. For example, some of the simple GPS theory and operation modules developed for Integrated Systems were used within a section of a second year level subject on advanced plane surveying. Students appreciated the wealth of information contained in the modules, and felt that
it provided a bridge between the lecture material and what was available in reference texts. However, they were discouraged when animations were slow to load or when necessary plug-ins were unavailable and needed to be downloaded onto home computers. This unfortunately detracted from the information and some students were unwilling to use it.

Anecdotal evidence also suggests that many of 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. However in all cases students were very positive about successful use of the animations and problem simulations, as well as the provision of a learning alternative and the flexibility of access for self-paced review and reflection. A frequent response was why all subjects in the geomatics course did not have some component of multimedia, particularly relating to visualisations.

There is relatively little scope for formal 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 assessment 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.

CONCLUSIONS

In summary, the multimedia projects described in this paper provide rich resources of information and visualisation or simulation of spatial concepts, measurement fundamentals, survey instruments and field processes. The presentation of comprehensive simulations of the field work processes, including instrument handling, prior to the students taking equipment into the field, leads to more efficient use of equipment. Efficient operation in the field enables 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 reiterates and augments the spatial concepts presented in formal lectures, utilising the dual mechanisms of presenting simulations in lectures and self-paced review by students.

Feedback and evaluation from students has in general been positive and encourages expansion of the current projects and further development in other areas of measurement science. However, as stated at the outset, the online material is an enhancement of the learning experience for undergraduate students, both complementing and providing an alternative to the conventional teaching methods of
lectures, tutorials and practice classes. There is no doubt that the experiential learning and regular contact with staff and other students embodied in a campus-based tertiary education is an essential component of the development of students toward their careers in geomatics, surveying and spatial information.

References