The Critical Importance of Practical Exercises in a Modern Surveying Curriculum

Craig Roberts
School of Civil and Environmental Engineering
University of New South Wales
c.roberts@unsw.edu.au

Bruce Harvey
School of Civil and Environmental Engineering
University of New South Wales
b.harvey@unsw.edu.au

ABSTRACT

The commodification of education has turned universities into businesses. They clamour for higher rankings on international league tables to elevate their status in the eyes of their future customers – their students. However, the role of graduates upon completion of their discipline remains unchanged. The community requires highly skilled and competent graduates who can contribute to society. As the universities' strategic models turn more toward an ever higher status, dedicated educators with a close connection to their profession are increasingly challenged to provide a well-rounded and useful graduate within the constraints of their institution. In surveying, practical exercises have always been an important part of the curriculum. Lecturers with some level of industry knowledge develop creative, educational practical tasks for students designed to challenge and deepen their knowledge. It is an expectation of the surveying profession that some level of practical knowledge has been attained at university. Accordingly, students also consistently report very positive feedback for practical exercises – indeed this is why they chose to study surveying in the first place. So how much practical education should be included in a modern surveying curriculum and how does it benefit the graduate, the lecturer and the profession? This paper details practical exercises in the surveying curriculum in the Bachelor of Engineering (Surveying) at the University of New South Wales (UNSW) and makes an argument for their retention in the surveying curriculum.

KEYWORDS: *Surveying, curriculum, practical exercises, education.*

1 INTRODUCTION

Surveying is a practical profession. It is contingent on universities to therefore equip graduates with the requisite skills to enter their chosen profession and develop into competent professionals. These skills are both theoretical and practical in nature. The surveying curriculum must therefore blend these two aspects of student education to allow students to gain a deeper knowledge of their discipline through study and practice.

In Australia, students are required to complete a 4-year degree from a tertiary institution. The Council of Reciprocating Surveyors Boards for Australia and New Zealand (CRSBANZ) set standards for the curriculums of the nine surveying programs offered in Australia and New Zealand that are pre-requisite for a professional qualification of Registered or Licensed Land

Surveyor in the corresponding jurisdictions (CRSBANZ, 2019). It is implicit in the assessment of these various tertiary qualifications that practical education is included. It should be stressed that practical education does not mean training. Graduates are expected to commence work having been exposed to the broad range of practical disciplines during their studies but are not expected to be experienced technicians ready to lead field parties on their first day (although some do).

In the last decade, Australian tertiary education institutions have focussed their attention toward international higher education ranking schemes such as the Shanghai based Academic Ranking of World Universities (AWRU, 2019), the Times Higher Education World University Ranking (THE, 2019) and the QS World University Rankings (QS, 2019) to name a few. Each of these 'league tables' relies on differing metrics. A single institution could be top 50 in the world by one ranking and not even in the top 100 by another.

In 2017, education-related travel services (including international student expenditure on tuition fees and living expenses) was Australia's third largest goods and services export, behind iron ore and coal, with a total value of over $30b per year. This has grown at an average of 8% per year over the last 5 years with a spike of 17.7% growth from 2015 to 2016 (DFAT, 2019). The cost of studying for one year in 2019 as a full fee paying international undergraduate student in engineering at the University of New South Wales (UNSW) is $46,320 (UNSW, 2019a). Postgraduate coursework and research degrees charge similar fees. This is clearly a very attractive business model for universities and a primary reason why Australian tertiary education institutions have focussed their attention toward international higher education ranking schemes (Gomes, 2014; Zhang and Tobias, 2015; Hare, 2018). Full fee paying students, especially from Asia, are persuaded by international rankings and will choose to study at a particular institution for that reason (Gong and Huybers, 2015; Gomes, 2016).

In order to maintain or climb international rankings, universities assent to the metrics applied by the various ranking schemes and steer their institutional strategies accordingly. This makes it very difficult for future educators, who may be dedicated to their profession but do not have a strong research track record, to succeed in a job application in this new competitive university paradigm. Successful academics in surveying programs may not even have a surveying background and very limited surveying experience or connection to the profession. These academics will likely not include practical surveying exercises in their teaching to the detriment of the students in the program and the profession. Not all academics in a surveying program require practical surveying skills, but at least some do.

There is a movement at UNSW and elsewhere to provide more digital online learning to teach larger classes efficiently. Lectures are recorded for students to view later, and online tutorial exercises and forums are provided for each course. We do this in surveying at UNSW, but we also provide on-campus, person-to-person learning, and practical field exercises are a key component of that.

This paper gives an overview of the practical education students are exposed to in the 4-year Bachelor of Engineering (Surveying) program offered at the University of New South Wales (UNSW Programs, 2019). UNSW also offers a 5-year combined degree Bachelor of Engineering (Civil) – Bachelor of Surveying program that includes all the surveying practicals described in this paper. The difficulties of running practical exercises are outlined, followed by a discussion of the environment in which surveying programs must survive. Finally, a case is made for the significance of such education to produce well-rounded, competent graduate surveyors.

2 PRACTICAL SURVEYING EDUCATION AT UNSW

Table 1 lists 29 practical surveying exercises offered throughout the BE (Surveying) program at UNSW including the approximate field and report writing time to indicate the complexity of the task. It should be noted that this list does not include the many and varied computer laboratory exercises offered in these and other courses throughout the program – especially those related to Geographic Information Systems (GIS), which for the purposes of this paper were not considered as surveying practical exercises.

It can be seen that the bulk of the field practical exercises occur in 2nd and 3rd year, with options in 4th year depending on which path a student will take in their senior program. An important part of the curriculum is the progression of knowledge in various aspects of the discipline. For example in regards to Global Navigation Satellite Systems (GNSS), Table 1 shows that handheld GNSS is introduced in 1st year and reintroduced with a Real-Time Kinematic (RTK) GNSS exercise in 2nd year without a full explanation of how it works. RTK is again used extensively at survey camp (GMAT3150) in 3rd year. Later in GMAT3700 in 3rd year, a deeper theory is presented and a full fast-static control survey is designed and carried out. By the end of 3rd year, students have a deeper understanding of GNSS positioning and could extend this in a final year thesis project if they choose.

A similar progression can be seen with regard to height determination. The first surveying field practical that students experience in their surveying careers is levelling (GMAT1110). In 2nd year they will use a rotating laser level and a precise digital level (GMAT2120). This is then used for a second-order levelling run, which is later checked in the same course by the same student groups using the total station leap-frog Electronic Distance Measuring (EDM) height traversing technique. A resection practical (GMAT2120) introduces students to the technique of trigonometric levelling and all its complexities. Students also use static and RTK GNSS for height determination later in the course. This again demonstrates how the concept of determining height is introduced and exercised using various methodologies. Students gain an appreciation for the advantages and disadvantages for the various techniques and their uncertainties, sometimes through bitter experience. Practical application of this theory promotes deep learning (Schön, 1990).

The practical exercises try to cover a wide range of instrumentation and methodologies. Indeed some of the instruments students may never use again and some of the techniques may be old and outdated. However, the fundamental surveying knowledge gained by the task ensures that the exercise remains relevant. This is illustrated in sections 2.1-2.3.

Students are also exposed to some of the very latest equipment. For instance, the School boasts a high-end laser scanner as well as a modern mobile laser scanner and access to a medium-accuracy, high-productivity laser scanner. The School recently purchased second-order digital levels, a suite of low-cost total stations for junior students, high-end Network-RTK (NRTK) capable GNSS receivers, and a top-end robotic total station designed for deformation monitoring. A range (8) of Remotely Piloted Aircraft (RPA), both fixed wing and copters, are available for student use for various projects.

Table 1: List of Surveying practical exercises in the BE (Surveying) program at UNSW.

Course	**Description**	**Field Time (hrs)**	**Report Time (hrs)**
1st year			
GMAT1110 – Surveying & GIS	Levelling	2	0.5
	Handheld GNSS/GIS	2	0.5
	Setout / Angles & Distances *	2/2	0.5/0.5
	Detail Field / Office *	3/3	1/1
ENGG1000 – Engineering Design	Design of photogrammetry capture of area using mobile phone or similar. Open-ended design project.	10	10
2nd year			
GMAT2500 – Survey Computations	Loop traverse practical	4	4
	Link traverse practical between MGA control marks	4	6
GMAT2700 – Geodesy 1	RTK GNSS	3	5
GMAT2550 – Least Squares	EDM validation and reflectorless EDM	3	3
GMAT2120 – Survey Instruments	Rotating laser level / digital level collimation test	2.5	0.5
	Precise digital level practical	5	8
	Resection by directions	3	6
	Mini practical: Tribrach validation, plunge test, middling up, vertical circle index & vertical axis test	3	1
	Leap-frog EDM height traversing	5	8
	Long line EDM practical	3	5
	Practical exam	0.7	0
3rd year			
GMAT3420 – Cadastral	Cadastral identification boundary survey	4	6
GMAT3100 – Survey Applications	Laser scanning field work (followed by processing)	2	
	Robotic total station	2	
	Several mini practicals, e.g. alignment, through glass	4	
GMAT3150 – Survey Camp	Control traverse design, field work and least squares	8	2
	Detail survey and CAD plans	8	12
	Road setout (total stations, digital levels and RTK GNSS)	8	12
	Tunnel setout	5.5	0.5
	Close-range photogrammetry	0.5	1.5
	Flying fox cable (with least squares curve fitting)	1	4
	Handheld GNSS image validation	1	3
GMAT3700 – Geodesy 2	Static GNSS design and execution	4	10
4th year			
GMAT4150 – Survey Camp 2	Large complex design project incorporating many instruments and techniques	40	110
GMAT4040/4050 – Research or Project Thesis	Research or project thesis (could include little or a lot of practical field work)	n/a	n/a

* These practical pairs are alternated for different years.

The only remaining ingredient is the creativity of the educators to develop worthwhile and challenging field surveying practical exercises to blend with the curriculum, challenge the students and promote their learning. An important element of the difference between training and education (specifically equipment and processing software) is that when students use equipment or software, the exercise is about experience in what is currently possible and learning in a way that they will be able to cope with new equipment and software during their careers.

2.1 Example Practical Exercise: Resection by Directions

In 2nd year, students are asked to use the resection-by-directions technique to coordinate a pillar in the Map Grid of Australia 1994 (MGA94) and Australian Height Datum (AHD) (GMAT2120). They have learnt the theory of 3-point resections by several techniques previously in session 1 (GMAT2500). The educators know the coordinates of the pillars and can therefore assess the result based on accuracy. This practical requires students to work on the roof of a tall building. They site various targets with known coordinates. Because they use pillars, there are no centring errors. They use modern total stations but do not measure distances.

Up to this point in the program, students have had little experience measuring precise directions. They learn about parallax, sighting, pointing, instrument-craft and measure 3 arcs to 6 targets each for some repetition. It is palpable to observe a students' confidence grow in just a few hours. The residuals in their results are testament to the improvement. They learn to look carefully at their raw data to discern blunders, suspect observations due to wind moving their target or grazing rays or shimmer. None of this can be taught in the classroom or online. It must be experienced. The threat of the field notes blowing off the roof top or being destroyed by rain reinforces a sense of care for the importance of raw data. These are all valuable lessons with no substitute. Circumstances are sometimes challenging and the students must adapt to field conditions.

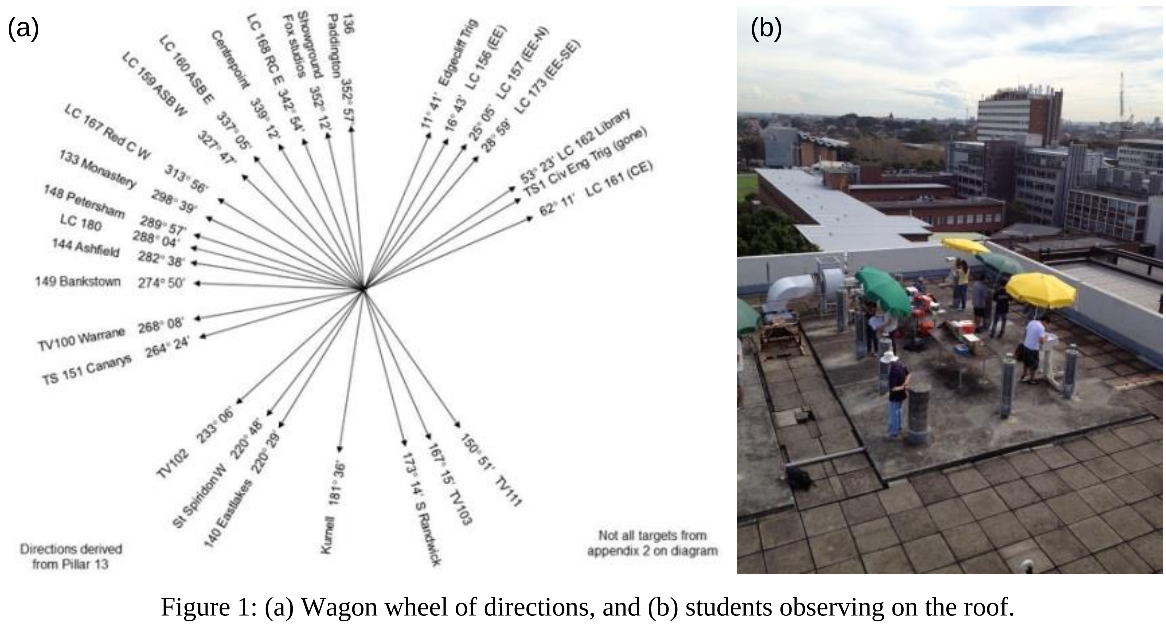

Figure 1: (a) Wagon wheel of directions, and (b) students observing on the roof.

The computations require students to statistically determine their best pointings and choose the best combination of 3 (from 6) pointings to be used to compute the coordinate of the pillar. Here students are faced with decision making. Is it better to use a pointing with a lower residual or a suite of pointings with a better geometry? These are fundamental surveying questions. Sometimes a target (TV antenna on the roof of an apartment block) has been unwittingly moved by several metres. The computations of various combinations of pointings can identify a rogue target. This is also an important outcome of this exercise. Lecturers make a list of those rogue targets that are suspected to have moved and must re-coordinate them.

2.2 Example Practical Exercise: EDM Long Line

Also in 2nd year, students exercise their theoretical knowledge of EDM first velocity corrections, reduction for geometric corrections to the ellipsoid and computation of the point and line scale factor (GMAT2120). The class is split into four groups who will visit the trigonometric stations along the cliffs of Sydney's eastern beaches at Malabar, Maroubra, Clovelly and North Bondi. Students prepare themselves in the survey store prior to the practical exercise and try to anticipate all contingencies. On the practical day, students arrive with their cars, load their gear and deploy to the field.

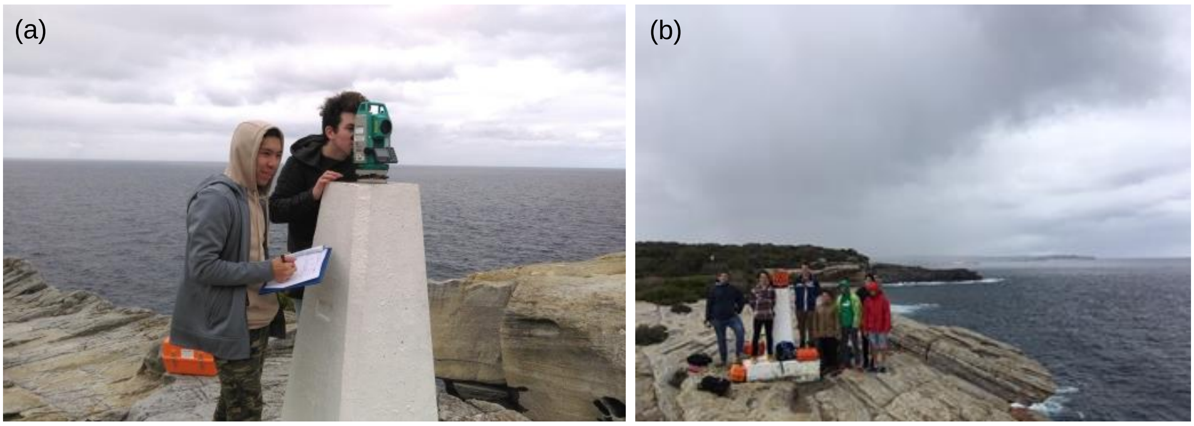

Figure 2: (a) Students at TS10329 BONDI NORTH, and (b) students at TS10644 MALABAR looking north.

The field task is very straightforward. Students simply set their EDMs to 0 ppm (i.e. using the standard temperature and pressure for the instrument) and measure raw distances 10 times to neighbouring trig stations as well as ambient temperature and pressure. With these observations, they are allocated a line (or lines) to compute by their lecturer and they perform all the necessary corrections individually by hand and compare with the join calculation for the known coordinates derived from the information on public record in the Survey Control Information Management System (SCIMS). Students follow the technical instructions and prepare a report and comment on the accuracy of the results.

The most important lesson of all from this EDM exercise is logistics and communications. Faced with a distance of 3 or 6 km to their neighbouring trig station, students experience how difficult it is to see over such a long distance even with the telescope of a total station. They learn that coordinating four field parties using radios (or maybe mobile phone apps) is more difficult than they had anticipated. Lots of time is wasted and sometimes some data is simply not recorded. The lecturers stand back and allow the students to self-organise. This is a very valuable experience in communications and leadership. The fact that it is located on the Sydney sea cliffs makes this exercise especially memorable for the students and for the most part reinforces their decision to become surveyors.

2.3 Are These Practical Exercises Outdated?

In reality, very few surveyors nowadays would measure a distance of over 6 km using EDM. Most would use GNSS for such long lines, but the point of the exercise is for students to see the magnitude of the corrections as they compute them step-by-step and comment on each.

When they use software to reduce distances, they will understand the steps taken in the reduction process and the magnitude of the various steps. The EDM exercise also facilitates an opportunity for students to experience the difficulty of complex logistics and communications for a larger survey project. Modern survey projects require these skills.

It could also be argued that resection by directions is a technique of the past. However, this exercise gives students an opportunity to improve their instrument skills and actually measure the quality of their work by comparing their computed coordinates with those of the 'known' result. There are also valuable lessons about uncertainty in observations and computations.

Another component of the resection exercise is to compute the AHD height of their pillar using single zenith angle readings and taking into account earth curvature and refraction. A weighted mean AHD height is computed, but students quickly learn that single shot trigonometric levelling is an inferior technique to other forms of height determination. Numerous trig stations in the NSW survey control network (SCIMS) were coordinated using this technique, so an appreciation of its limitations remains valuable.

2.4 Survey Camps

Survey camps have always been a part of the surveying curriculum. These are extended field exercises often in a different location away from campus where an intense period of surveying field work is undertaken and subsequent computations as well as plan and report preparation are carried out back in the office. This is not unlike what a professional might do in their future career.

2.4.1 GMAT3150: Field Project 1 (3rd Year Survey Camp)

GMAT3150 is a 1-week survey field camp without any lectures or exams. Students attend camp at the NSW Sport and Recreation facility in Berry (previous camps were held at Morpeth). All accommodation and catering is arranged months in advance by the academic coordinator as well as the financial arrangements. Students pay a partly subsidised cost for the week.

After a Work Health and Safety (WHS) briefing and site orientation, student groups of 3 commence their first high-precision control traverse. This is used as the framework for their following detail survey using total stations. All data is recorded in the instrument and students are encouraged to fill in some parts of their survey with RTK GNSS. This exercise is scheduled to be completed in 2 days. Least squares computations (Harvey, 2016) are carried out in the evening, and students have the opportunity to take extra observations if necessary. They must ensure their unprocessed raw data is at least correct before returning to university. Neighbouring student groups' detail areas overlap, so later during session at university, students are required to import the data from a neighbouring group to produce a combined plan. They can compare their detail survey directly with their colleagues. If it does not import or fit seamlessly, then they must explain why. This simulates real-world scenarios on large projects with multiple survey crews in operation.

Prior to the camp, the students have designed the centreline of a road 360 m in length using Computer-Aided Drafting (CAD) software for setout in the field. They set out using total station radiation techniques in MGA94 and check using RTK GNSS. A detail survey 15 m either side of their road corridor is undertaken for design later at university. This also gives a coarse check on the levels of the set out pegs, which are accurately levelled using digital levelling. Later, back a university, students design a road in CAD software adhering to prescribed design constraints. They produce longitudinal, cross section and plan views with all associated volume and road design computations, including super-elevation, in a professional written report.

The last exercise requires students to precisely set out a tunnel 500 m in length. They must first set out their allocated starting point as accurately as possible. Thereafter they must set out their allocated finishing point and imagine that they are in the tunnel as they do this. Therefore they can only plunge over their instrument and cannot use external control. The starting and ending points are not inter-visible. This is an exercise in accuracy and precision. Students measure to check marks at either end of their tunnel and supply these radiations to their lecturers for confirmation. Students do not know the coordinates of the check marks.

Other minor tasks during the camp include a terrestrial photogrammetry exercise, curve fitting to the catenary of a 300 m flying fox cable and satellite image validation using handheld and RTK GNSS and comparison with ELVIS (ELVIS, 2019) data.

2.4.2 GMAT4150: Field Project 2 (4th Year Survey Camp)

GMAT4150 is a capstone course for final-year surveying students whereby they undertake a challenging project for a ‘client’ (the course coordinator) and act as a group of survey consultants. There are no lectures and no exams. The project may be on campus, or off campus in camp mode. The project task can be open-ended and often the outcome may not be known at the start. Students must organise themselves, often appointing a project manager who coordinates all tasks. Students conduct weekly meetings, set tasks, design their survey, arrange logistics, perform the survey and prepare a final report based on their work.

The focus of this course is on the quality of the education and completing the challenging tasks presented. The assessment is a mixture of group work and individual contributions. Students prepare all of their own WHS documentation, organise how best to communicate amongst the group and log their hours. This is akin to costing the job.

A major part of the assessment is through self-assessment (Roberts and Harvey, 2018). This is carefully explained to students as not an abrogation of responsibility on behalf of the course coordinator, but rather an opportunity for students to act as professionals and provide honest, critical assessment of their own performance and that of the group and nominate an overall mark for themselves. Results are usually very close to the quantitative assessment as determined by the course coordinator. The qualitative comments are often very gratifying. In 2018, students undertook a camp at Wellington in the Central West in conjunction with civil engineering students from the school (Roberts, 2018).

2.5 Practical Exam

As part of the final assessment for 2nd year students, a practical exam is set. Students are required to coordinate an unknown mark using basic plane surveying techniques. The lecturer prepares the students during the session and explains that the purpose of the practical exam is to give the students confidence in their abilities. It is performed under time pressure, but by the end of 2nd year students have undertaken more than 10 field practical exercises and this final exam is relatively straightforward.

During the practical exam, students are given a locality sketch and instrument and in the allotted time they must find their relevant mark, setup their instrument, measure a distance and an angle and perform the required computations using a hand calculator. They are given coordinates for their instrument station and a known backsight. Therefore they must be able to compute a join and a radiation and are assessed on their setup, field notes, computations and accuracy. Students present their result, are shown the final coordinate and can see if they are within 5 mm of the known mark. Scoring 10/10 gives students a great sense of pride and confidence. Students who perform poorly are invited to stay and re-compute their observations and usually find their errors, which they will likely never make again – an example of deep learning.

3 DIFFICULTIES CONDUCTING PRACTICAL SURVEYING EXERCISES

It requires creativity to design field practicals and energy to run them. There needs to be enough equipment and it must be in good working order with charged batteries. Students, who may be using these instruments for the first time, require simple instructions to operate the gear. The task should be challenging but achievable in the time allotted.

In recent times, running practical exercises has become much harder with WHS requirements becoming increasingly onerous. Heads of Schools are held personally liable for accidents, so requisite paper work must be completed prior to practical exercises. Survey camps held off campus require an extra level of protection. However, all of these WHS requirements can be folded into the education by presenting this to students as the normal process for working as a surveyor in the workplace.

The School can no longer afford to employ a dedicated storeman. Instead, a professional officer and relevant academics maintain the equipment as part of their work. An online booking system has been developed, and a central repository for instruction manuals and relevant documents is made available via an intranet link. The School provides a budget for equipment maintenance and competitive grants for purchasing new equipment.

In order to minimise the workload, a ‘culture of care’ is promoted to students during teaching and exercised during surveying practicals. Students are told that this is ‘their gear’ too and they should look after it accordingly. If they notice a problem or break any equipment, they report it. Some minor practical exercises (mini practical GMAT2120, see Table 1) ask students to validate tribrachs, check the horizontal collimation error of instruments and list their findings. Students learn about equipment maintenance but also feel like they are looking after their own gear. Students learn about battery charging, unclamping wet tripods and learn where all the equipment is stored. This culture reduces the workload for the School staff but also promotes an understanding of care for equipment that students can take to the workplace.

The logistics for staff organising practical exercises on campus are increasing over time. It is difficult to find suitable timeslots in the university-wide centrally managed timetabling system. A timeslot of 5 hours on a Friday from 12-5 pm for large exercises has proven to be the best option as this can easily extend longer for students who require more time. A 2- or 3-hour timeslot is the norm. Finding a week during session for a survey camp (GMAT3150) is very difficult and requires other classes during that week to be moved elsewhere in the session.

For short timeslots of only 2 hours, equipment needs to be transported to the field. Too much time is lost if students pick up the equipment from the store, walk to the field and then return it. Staff therefore need to organise a vehicle for hire prior to the practical, pick up the gear from the store, transport to the Physics Lawn on campus (one of the few remaining green spaces), and return the gear and the vehicle after the event. But the green space must also be booked and security must be informed of the vehicle, length of time and registration or risk a parking fine. Roof space has to be booked for use for surveying exercises, and academics have to have completed the relevant WHS certification to access the roof. Students need to wear the correct Personal Protective Equipment (PPE). They learn to set up their instruments out of the way of vehicle and pedestrian traffic to ensure safety and for consideration of others on a busy campus.

Educators need to ensure that sufficient survey marks are available to support the practical exercises. Indeed academics continually maintain the UNSW campus network. Survey marks are constantly destroyed as a result of construction works on campus. The UNSW campus network is like a mini geodetic network that students help to maintain. Assessment can offer extra marks for students who have achieved the required precision in their exercises and they can submit their results in a FIXIT4 format that can be combined into a new campus network adjustment (Harvey, 2019). As new survey marks are placed by staff, new student exercises are designed to coordinate these marks and the raw observations from students help to maintain the campus network. It should be noted that the campus network and the Berry survey camp network are not merely a list of coordinates of points but a complete set of observations that can be readjusted at any time.

The School provides excellent support to the Surveying and Geospatial Engineering (SAGE) group. In recent times, many new modern surveying instruments have been purchased, however this presents another problem for academic staff. It is very difficult to learn all of the instructions for using all of the equipment and all of the software associated with the new equipment. Thesis projects are often devised for new equipment or used in more open ended projects such as those undertaken in GMAT4150 (see section 2.4.2). As academics gain experience and confidence with these new devices, new exercises start to infiltrate the senior program and gradually filter down as the curriculum evolves with new techniques. It is always the most difficult task to dispense with an older technique that may no longer be relevant or educationally beneficial. For example, cyclic error in EDM is no longer taught in practical exercises at UNSW. This makes way for other tasks elsewhere in the program.

4 PRESERVING PRACTICAL EDUCATION

Universities align new staff recruitment toward the strategic objectives of the institution. In the current competitive environment, for a high-ranking, research-intensive university, a PhD is a minimum qualification. A strong research track record promising potential to grow and attract future research dollars (and all associated kudos) to an institution is valued highly by university recruiters. Research areas associated with surveying might include GNSS, remote sensing, GIS, photogrammetry or land administration. It is becoming more and more difficult to find a promising young researcher with a connection to the practical profession of surveying.

Other Australian tertiary institutions are addressing this issue in various ways. Some employ temporary fractional lecturers to teach practical surveying based courses. Some outsource field practicals as either 'residentials' or field camps and ask experienced surveyors from the profession to take these classes. However, the disadvantage here is that professional surveyors are not professional educators and do not have the experience to design and run field projects with the best educational outcomes. This can improve over time, but only if the professional surveyors continue to contribute and closely liaise with academic staff.

Recently at UNSW, a new category of academic has been implemented called an education focussed academic (UNSW, 2019b). This new category recognises the importance of teaching as a fundamental role for an academic and indeed that the lion's share of money flowing into universities derives from undergraduate teaching. Perhaps this promising development will offer a pathway for new junior staff from the surveying profession to be mentored into the academic world and complete a PhD whilst teaching into a surveying program.

4.1 Student Feedback

Practical surveying exercises almost always receive positive student feedback and a plea for more. Usually more than 85% of respondents mention practicals specifically in their qualitative feedback. Students report that they finally understand the material presented in lectures, or did not realise the importance of a particular detail until they actually experienced it in the field. A student culture develops during practical exercises. Perhaps it is bonding through adversity or just sheer enjoyment of performing a technical task outdoors with real equipment and trying to achieve a measureable outcome. It is hugely satisfying when good results within a specified tolerance are achieved as planned – both for the student and the educator.

The following are recent examples of student feedback from 1st year:

- "The practical exercises were really enjoyable and helpful in the sense that they allowed for consolidation of lecture material and also provided a hands-on way to visualise key concepts."
- "This is the only course that I've done in my first year that allowed me to really experience what it would actually be like to work in the profession that the course was building towards."

More senior years provided similar comments, including: "Hands-on experience, very detailed feedback." A 3rd year student commented after completing GMAT3150 – Survey Camp: "I feel like a different person. I feel much more confident and I have really learnt something."

One of the important metrics for a university are the Quality Indicators for Learning and Teaching student experience surveys (QILT, 2019). The survey is designed to collect information that will help both higher education institutions and the government improve teaching and learning outcomes, and reports on multiple facets of the student experience. It is clear from the comments above that practical field exercises in surveying would contribute strongly to a positive experience for surveying students.

5 CONCLUDING REMARKS

Hands-on practical exercises are essential to a surveying education. They take a lot of effort to design, prepare and teach, but they also yield consistently excellent educational outcomes and positive feedback from students. Educators require imagination and energy to continue to design and conduct these exercises in order to keep them relevant and make use of evolving technology. Practical field classes provide students with an opportunity to explore and experience surveying without some of the consequences of mistakes. This is teaching and not research, and from an accounting point of view survey camps and field practicals might be hard to justify to university leaders. This is a dangerous misunderstanding, especially when new staff recruitment is considered. For employers, professional associations, as well as the Board of Surveying and Spatial Information (BOSSI) and CRSBANZ who set the standards for surveying education, practical education is seen as crucial. Indeed, without the requisite of practical education, surveying programs will not be accredited by professional organisations and will therefore lose their value and relevance for completing students. Practical education in surveying programs remains an important component of a modern professional surveying qualification.

ACKNOWLEDGEMENTS

We would like to thank our Professional Officer Dr Yincai Zhou for his tireless support and continual new ideas to improve our survey store and operations that support practical teaching at UNSW. Also thanks to the School of Civil and Environmental Engineering for their support to enable new equipment purchases and budget for instrument maintenance.

REFERENCES

AWRU (2019) Academic ranking of world universities, http://www.shanghairanking.com/ (accessed March 2019).

CRSBANZ (2019) Council of Reciprocating Surveyors Boards of Australia and New Zealand, http://www.surveyor.asn.au/ (accessed March 2019).

DFAT (2019) Australia's top 10 goods & services exports and imports, https://dfat.gov.au/trade/resources/trade-at-a-glance/Pages/top-goods-services.aspx (accessed March 2019).

ELVIS (2019) ELVIS – Elevation and depth foundation spatial data, http://elevation.fsdf.org.au/ (accessed March 2019).

Gomes C. (2014) Australia loses international students at its own peril, *The Conversation*, 29 July, https://theconversation.com/australia-loses-international-students-at-its-own-peril-29377 (accessed March 2019).

Gomes C. (2016) Rising players in higher education: The countries to watch out for, *The Conversation*, 29 July, https://theconversation.com/rising-players-in-higher-education-the-countries-to-watch-out-for-62964 (accessed March 2019).

Gong X. and Huybers T. (2015) Chinese students and higher education destinations: Findings from a choice experiment, *Australian Journal of Education*, 59(2), 196-218.

Hare J. (2018) It's still worth it for overseas students to study in Australia, but universities could be doing more, *The Conversation*, 22 November, https://theconversation.com/its-still-worth-it-for-overseas-students-to-study-in-australia-but-universities-could-be-doing-more-107180 (accessed March 2019).

Harvey B.R. (2016) *Practical least squares and statistics for surveyors*, Monograph 13 (3rd edition), School of Surveying and Spatial Information Systems, UNSW, 332pp, ISBN 0-7334-2339-6.

Harvey B.R. (2019) Survey computations. A free online textbook edited and partly authored by Bruce Harvey. Currently available at http://www.sage.unsw.edu.au/Textbooks (accessed March 2019), 291pp.

QILT (2019) Quality indicators for learning and teaching: Student experience, https://www.qilt.edu.au/about-this-site/student-experience (accessed March 2019).

QS (2019) QS world university rankings, https://www.topuniversities.com/qs-world-university-rankings (accessed March 2019).

Roberts C. (2018) Surveying the UNSW research station (Wellington, NSW) to enhance groundwater engineering student outcomes, Presented at *SSSI NSW Regional Conference*, Wollongong, Australia, 14-16 November.

Roberts C. and Harvey B. (2018) GMAT4150: Field Projects 2, course outline, https://www.engineering.unsw.edu.au/civil-engineering/student-resources/course-information/past-course-profiles/course-profiles-2018 (accessed March 2019).

Schön D.A. (1990) *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions* (1st edition), Jossey-Bass, San Francisco, 376pp.

THE (2019) Times Higher Education world university rankings, https://www.timeshighereducation.com/world-university-rankings (accessed March 2019).

UNSW (2019a) Tuition fees 2019: UNSW Engineering for international students, https://student.unsw.edu.au/fees-engineering-international (accessed March 2019).

UNSW (2019b) Education focussed careers, https://teaching.unsw.edu.au/education-careers (accessed March 2019).

UNSW Programs (2019) BE in Surveying, https://www.engineering.unsw.edu.au/civil-engineering/sites/civil/files/uploads/programs/program2019/GMATDH3707.pdf (accessed March 2019).

Zhang Z. and Tobias S. (2015) The rise of China: A threat or opportunity for Australian universities? *The Conversation*, 10 November, https://theconversation.com/the-rise-of-china-a-threat-or-opportunity-for-australian-universities-49145 (accessed March 2019).