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The Postgraduate Geothermal Energy Course Update: Geothermal Institute, New Zealand

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ABSTRACT

Geothermal energy training is a very specialised with only few established postgraduate programmes available worldwide. In this paper, we discuss the background, teaching philosophy, course content, student cohort, funding and recent enrolment trends in the New Zealand course. The Post Graduate Certificate in Geothermal Energy Technology (PGCertGeothermTech) taught at the University of Auckland, New Zealand since 2007. It is a one-semester (4 month) course for Science and Engineering graduates, developed in response to the demand for trained engineers and scientists to work in geothermal exploration and development nationally and internationally. The programme is industry-oriented and is designed to bring together graduates from different disciplines in science and engineering. The course is very condensed; concept rich and organized into two teaching blocks of six weeks each, followed by a short project. There are two major field trips of one week each, which comprise 20% of the course. Running this programme has many challenges such as the diverse technical skills needed to teach this programme, which are not all available within the University. The programme is expensive to run due to the high cost of the two week-long field trips. At the same time, student numbers have to be limited for this level of applied teaching and for health and seafety considerations associated with the field-work. The course coordinator and main academic staff carry out most of the teaching and fieldwork and are strongly involved in the selection of material covered by the external lecturers and industry experts. This reduces the course overhead in terms of number of full time academic staff and prevents repetition of material covered by multiple lecturers, which also ensures a consistent course structure. There has been significant changes in student's enrolment trends in the past few years. While the number of students attending the different geothermal papers/modules has been relatively stable, the number of students completing the full PGCertGeothermTech degree has declined. This is related to the strong interest in the multi-discipline Master of Energy (taught) program where students carry the credit from doing the geothermal papers toward this degree. Students from the Master of Energy program also carry out a six months research project on geothermal topic.

1. INTRODUCTION

Geothermal energy training is a very specialised area with only two established postgraduate (PG) programmes available worldwide. The two-semester geothermal PG Diploma at the Geothermal Institute, the University of Auckland ran from 1979 till 2002 when the government funding of the Geothermal Institute ceased. The programme was restarted in 2007 as a one-semester (60 points) PG Certificate in Geothermal Energy Technology (PGCertGeothermTech) in response to the increasing demand for trained engineers and scientists with the boom in geothermal exploration and development in many countries around the world. The programme is very practice oriented and is designed to bring together graduates from different disciplines in science and engineering.

The PGCertGeothermTech is offered in Semester two to both local and international students with international students accounting for more than 90% of our students; a similar trend was observed during the PG Diploma (1979-2002). 204 Students have completed the PGCertGeothermTech since 2007 with 91 students taking the credit from doing the GEOTHERM papers into other degrees.

Running this programme has many challenges such as the diverse technical skills needed to teach this programme, which are not all available within the University. The programme is expensive to run due to the high cost of the two week-long field trips. At the same time student numbers have to be limited for this level of applied teaching and for health and seafety considerations associated with the field work.

History has witnessed the demise of several similar geothermal courses around the world when their external funding stopped (see the Table 1 below):

Table 1. History of main PG Geothermal programmers around the world

Institution	Country	Year Started	Year Stopped	Duration
Pisa	Italy	1970	1992	6 months
Kyushu	Japan	1970 2016	2001 Running	2 then 4 months 4 months
Auckland	New Zealand	1978 2007	2002 Running	9 months 4 months
Reykjavik	Iceland	1979	Running	6 months

We have taken this past experience into consideration when designing the current PGCertGeothermTech. This involves running the course once a year, as we do not see the market for running the course twice a year.

Admission statistics for the past 5 years (2014-2018) are included in the Table 2 below:

Table 2: Admission statistics of the full PGCertGeothermTech 2014 - 2019

		Applied	Offered	Enrolled
2014	Domestic	5	4	2
	International	99	50	39
2015	Domestic	2	1	1
	International	82	51	19
2016	Domestic	7	2	1
	International	70	24	5
2017	Domestic	4	2	2
	International	49	27	6
2018	Domestic	3	2	0
	International	36	19	4

Table 2 shows that:

The number of the students enrolled in the PGCertGeothermTech course is dropping since 2014. This is because in 2013-2014 we had a contract with PERTAMINA Geothermal Energy Pty, Indonesia to train additional 15 students/year.

Since 2016 most of the students enrolled in the different GEOTHERM papers (Table 3) are enrolled in the 180 point Master and 120 point Master of Energy degrees, not many students complete the PGCertGeothermTech. This was very evident in 2016 when the 180 point Masters was introduced. Therefore, fewer students are do the geothermal project (GEOTHERM 689).

Since 2016 less students are taking GEOTHERM 603 (geothermal exploration) which was not run in 2018 due to the limited enrolments. This can be related to the recent slowdown in geothermal explorations worldwide (see Zarrouk, 2017).

The number of enrolments are relatively stable at an average of >60 enrolments/year across the different GEOTHERM papers (Table 3 and Figure 1), which we feel to be sustainable.

Table 3: Admission statistics in the different GEOTHERM papers including Master of Energy students 2014 - 2019

	GEOTHERM 601	GEOTHERM 602	GEOTHERM 603	GEOTHERM 620	GEOTHERM 689	Total Enrolments
2014	38	38	18	30	41	165
2015	21	21	7	14	20	83
2016	16	16	3	10	5	50
2017	24	24	7	18	5	78
2018	28	28	0	26	4	86
2019	18	18	5	12	10	63

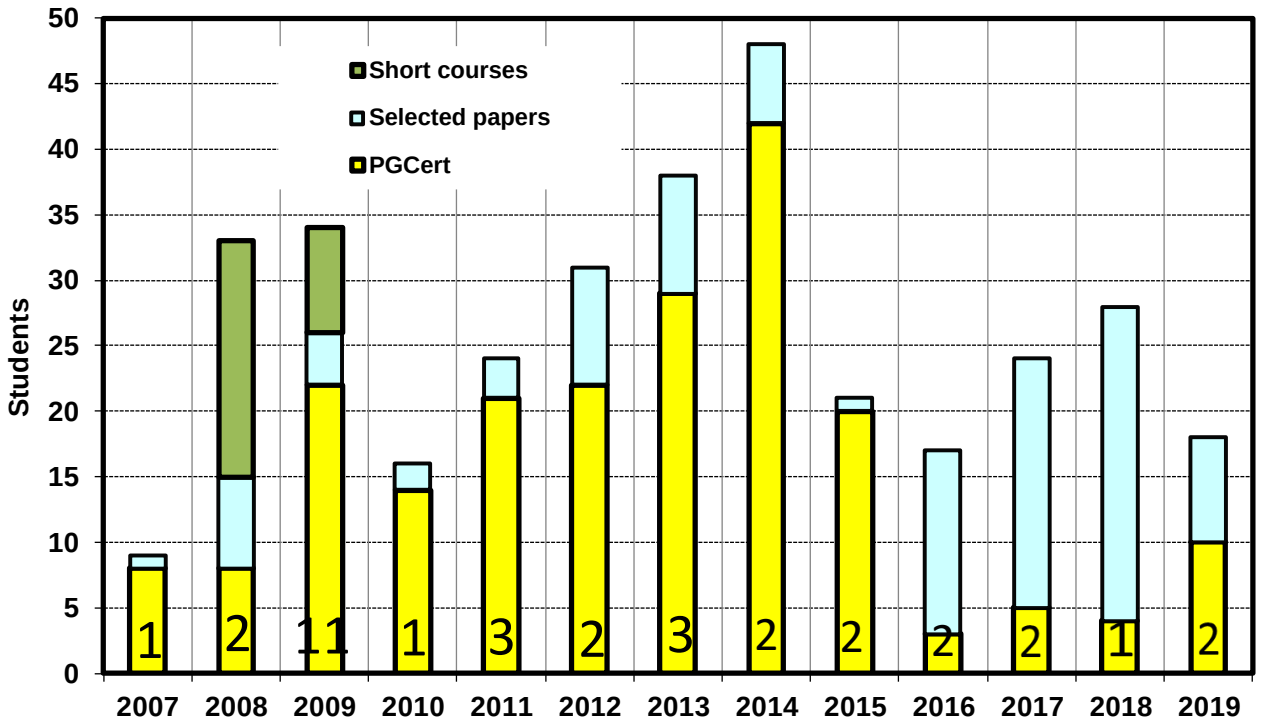

Figure 1. Annual number of student's enrolment in the PGCert, selected papers and short courses The numbers within the yellow bar indicates the number of domestic students attending the full PGCert course each year.

The PGCertGeothermTech course also provide an ongoing stream of ME, MSc and PhD students back into the university. I am currently supervising four PhD, three ME and one MSc (co-supervised with the faculty of science), all graduates of the PGCertGeothermTech course.

2. PROGRAMME PURPOSE AND DESIGN

The PGCertGeothermTech is designed to accelerate the development of geothermal expertise amongst young graduates and professional engineers and scientists, and thus support them in starting and/or advancing their career in in the geothermal industry. It has been designed as a block structured concept-rich and high-quality postgraduate qualification for professionals with an engineering (BE) or science (BSc) background. The first part comprises of a fixed set of compulsory courses in both Geothermal Engineering (paper GEOTHERM 602) and Geothermal Earth Science (paper GEOTHERM 601) to the value of 30 points. Given the diversity of student academic background, the first two weeks of these courses are dedicated to bridging the knowledge gap and bring the students to a common ground in knowledge. This is when the engineers learn more about earth science (geology, geochemistry, geophysics) while the earth scientists learn the engineering fundamentals (thermodynamics, fluid mecahnics, heat transfer). This period also serves as a refresher for returning students who have been outside academia for some time. Then the student attend a one week field trip to geothermal sites of intrests, which help link theory to practice

In the second part of the programme, the students have the option to learn more about either geothermal engineering (GEOTHERM 620) or geothermal exploration (GEOTHERM 603). The students then carry out an industry-based geothermal project (GEOTHERM

689) to apply, in a practical setting, the knowledge they have gained through out the coursework and submit a report on some industry aspect of geothermal exploration, development or exploitation.

The PGCertGeothermTech programme does not include distance learning courses, due to the condensed block (of six weeks) structured nature and the integrated field based and class based education structure. This point is made very clearly on the programme webpage and information pack.

There are two field trips (five days each) to the Taupo Volcanic Zone in the central North Island of New Zealand. The first field trip is during the GEOTHERM 601 and GEOTHERM 602 papers in the first part of the semester. The second field trip is during GEOTHERM 603 and GEOTHERM 620 papers in the second part of the semester. There are also several day trips to visit geothermal companies and sites of geological or geothermal importance. The field trips help to complement the theory with practice, cement concepts and allow the lecturers to building further knowledge. By the end of this programme the students will have seen five different geothermal power stations, two geothermal drilling rigs sites, four steam fields, eight examples of the direct use of geothermal energy and five different geothermal systems.

Student safety during the field trips is a top priority and we develop a health, safety and wellbeing (HSW) risk assessment –field activity assessment for each field trip. Since the start of the programme in 2007, there has been no accidents or injuries and we are proud of our zero harm (to human or nature) policy.

Emphasis in the programme is on the development of practice-related, high-level knowledge, practical lab and field skills rather than purely academic knowledge. However, some of our graduates have continued their academic studies at ME and PhD levels. Currently I am supervising 3 ME and 4 PhD students all graduates of the PGCertGeothermTech course.

Typically students come from a broad range of technical disciplines (some have ME, MSc and PhD) and vary in age (21-65 years old) and work experience, but they all share a commitment to enhance their skills in order to accelerate their career options in geothermal energy technology both in New Zealand and overseas. Most of the local students are not in employment when starting the programme. International students are generally in full-time employment and some choose to do the programme over two years due to their employment commitments back home and, hence, the block structure of the courses. This arrangement works well for local professionals doing the PGCertGeothermTech course.

The students are mostly (> 85%) international (Figure 2) with different academic backgrounds, gender (Figure 3), ages (Figure 4) and ethnicities. Interestingly, the top performing students are in the age group between 30-34 years old due to their maturity and industry experience.

Students will have completed prior study (BE or BSc) before commencing this degree and may have had work/life experience as well. Most students have been in industry for some time and have decided that they need further knowledge, skills and experience to advance their careers as experts in the geothermal industry.

Female student numbers are unfortunately low (26% average). However, we have been working with the Woman in Geothermal (WING) interest group to encourage more female students into the PGCertGeothermTech programme and the geothermal industry. We also encourage through direct communications with sponsors to send “female students”.

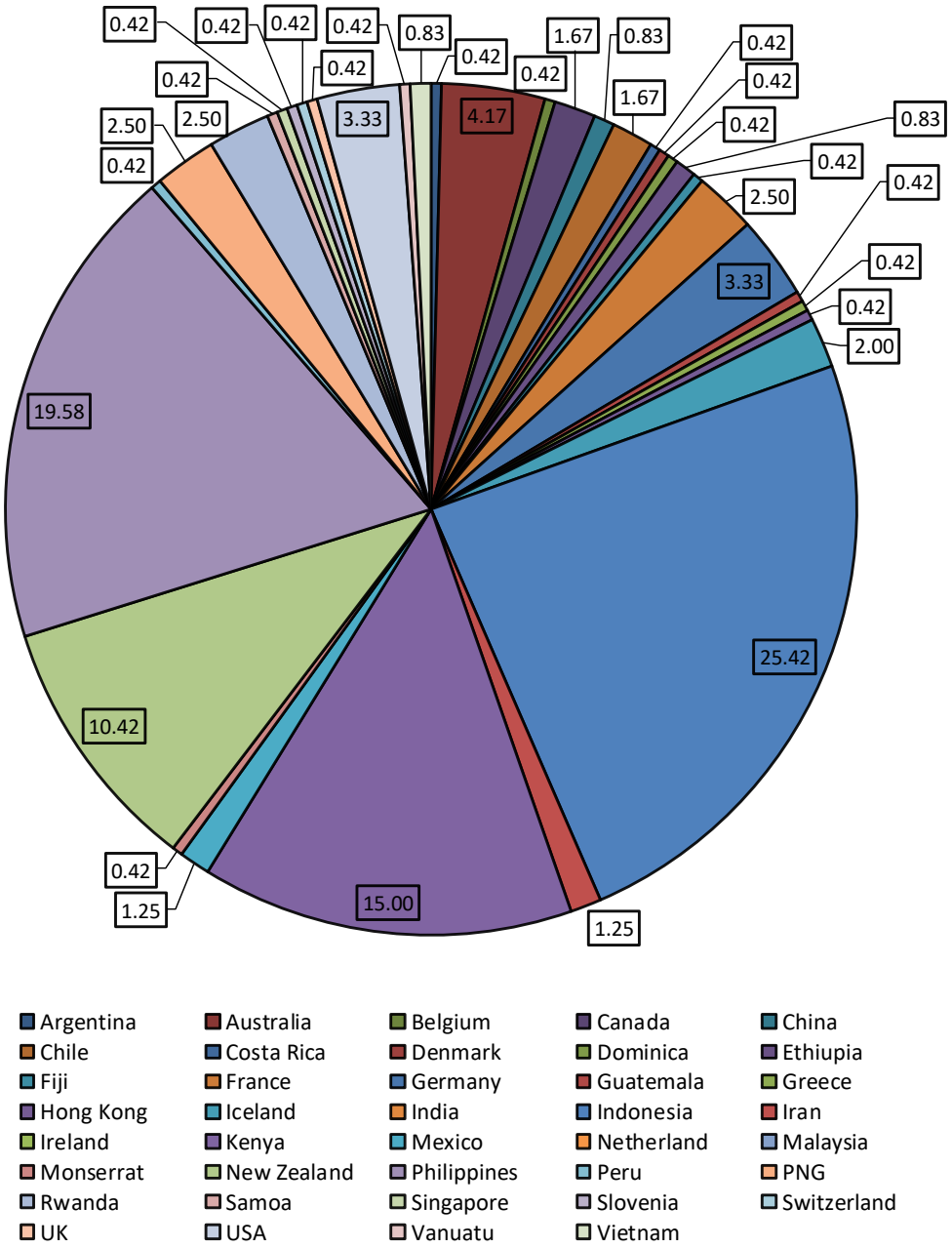

Figure 2. Students proportion by country for the past thirteen years (2007-2019).

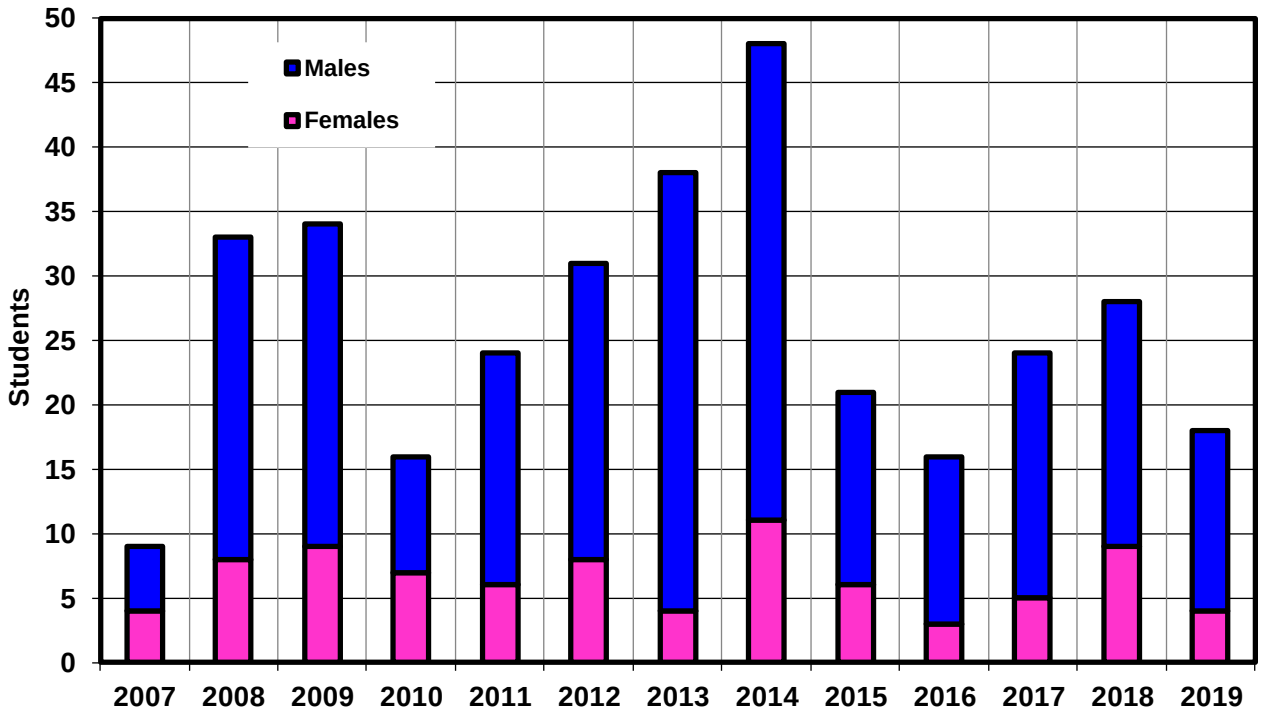

Figure 3. Gender distribution for the PGCertGeothermTech students since starting the course in 2007.

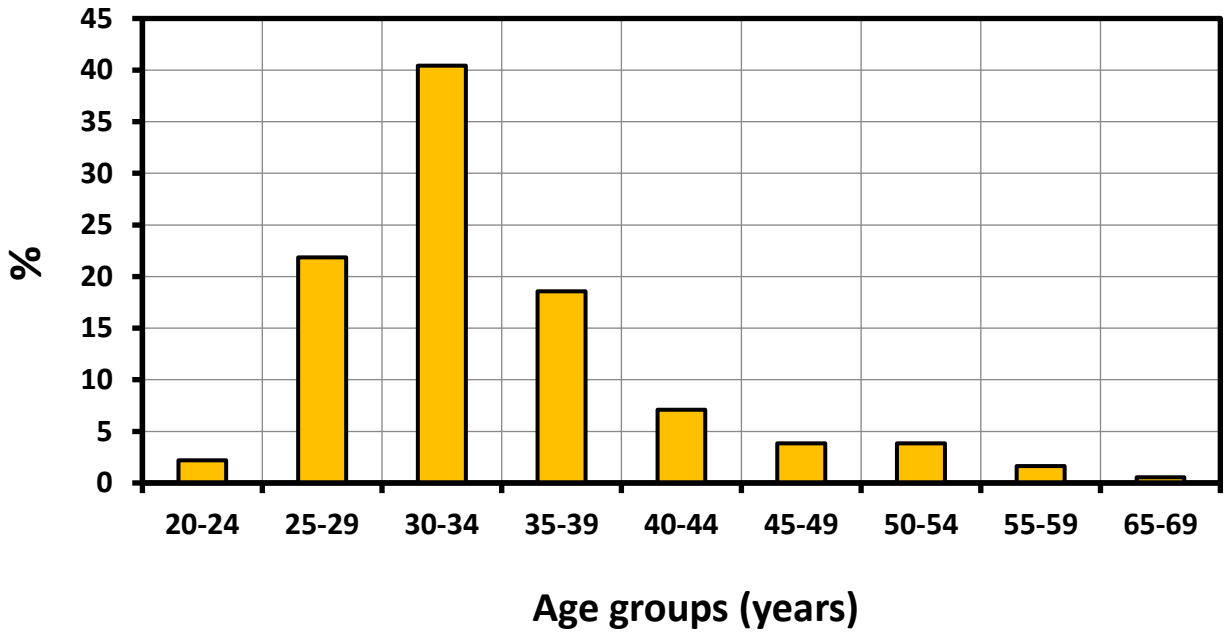

Figure 4. Students age distribution for the PGCertGeothermTech course, since starting the course in 2007.

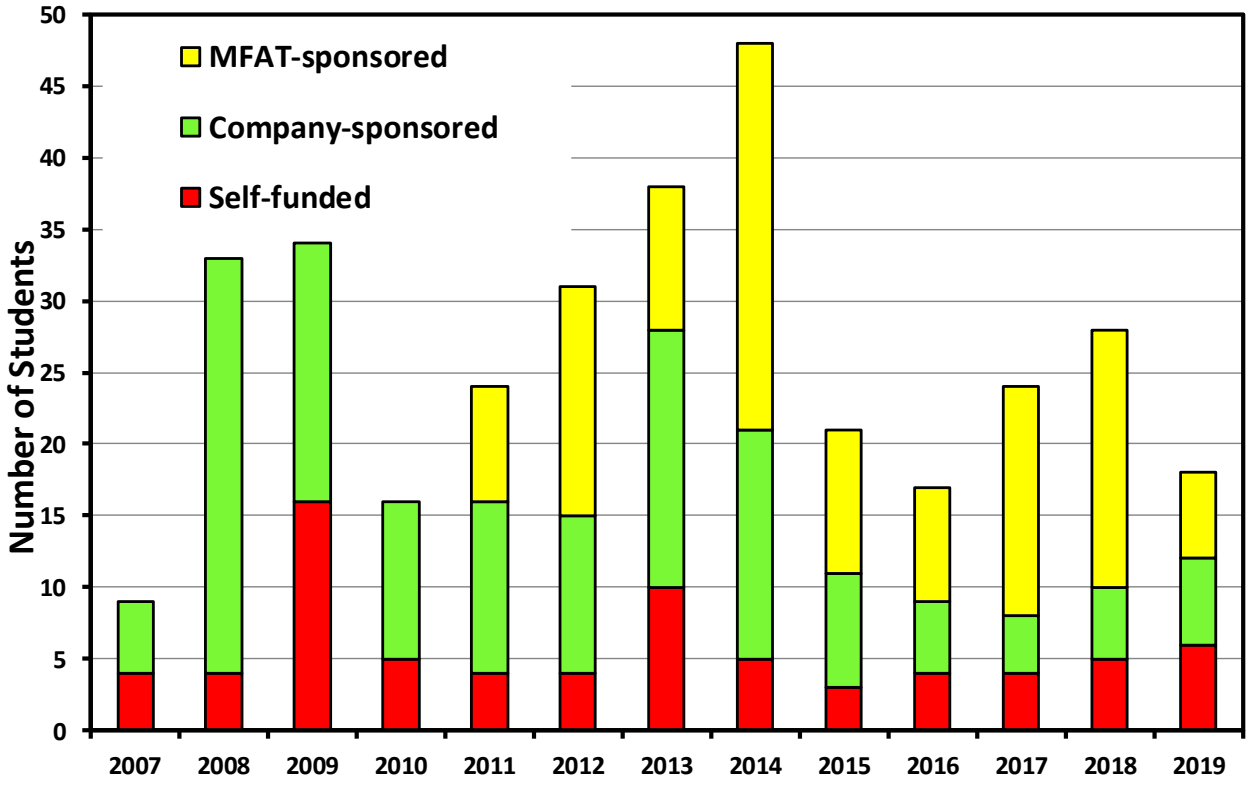

Figure 5. Support for students to attend the PGCertGeothermTech, proportions for each year.

3. CURRICULUM CONTENT AND ORGANISATION

The curriculum of the PGCertGeothermTech programme consists of two compulsory courses (six weeks long) papers: Geothermal resources and their use (GEOTHERM 601) and Geothermal energy technology (GEOTHERM 602) from the Department of Engineering. These courses have been designed to provide a comprehensive and broad overview of the geothermal energy technology at postgraduate level.

Two advanced electives are included in the second part of the programme (six weeks long), the students have the option to learn more about either geothermal engineering (GEOTHERM 620) or geothermal exploration (GEOTHERM 603).

There are two field trips (five days each) to the Taupo volcanic zone in the central North Island of New Zealand. The first field trip is during the GEOTHERM 601 and GEOTHERM 602 papers in the first part of the semester. The second field trip is during GEOTHERM 603 and GEOTHERM 620 papers in the second part of the semester. The field trips (20 % of the course time) are integrated with the academic teaching to build student confidence in understanding the framework of geothermal fields: assessment, development, and utilization.

The learning outcomes are:

- Understand the principles of geothermal energy using the fundamentals of fluid mechanics thermodynamics, heat transfer, geothermal geology, geochemistry and geophysics.
- Understand the limitation of these fundamentals when applied to real geothermal problems and the methods used to accommodate for these limitations.
- Develop a multi-disciplinary approach to geothermal energy development and have an appreciation of the contribution from all disciplines.
- Develop applied field skills such as mapping, sampling, hand sketching, taking short field notes and field measurements using a variety of tools and simple but effective field techniques.
- Gain competence with the use of geothermal reservoir simulators, well bore simulators, well test analysis and geological modelling tools.
- Validate, interpret solutions and outputs from geothermal reservoir simulators.
- Develop confidence in applying the analytical skills gained during the courses on a real geothermal problem (case study).
- Improve the student presentation and technical writing skills when presenting their work during seminars and when writing long technical reports.

There is no scope for the students to select additional electives outside this range of papers due to the block structure of the courses and it's highly specialised nature. However, most students these days choose to take the credit from doing the GEOTHERM papers into other degrees (mainly the 120 MEnergy and the 180 points Masters) with few students from the faculty of science. We also get some students through The University of Auckland international students exchange program attending the full PGCertGeothermTech course.

All PGCertGeothermTech students are required to complete a compulsory 15 points project (GEOTHERM 689) of four weeks duration. The project must be approved by the PGCertGeothermTech course coordinator, and may take the form of a survey and evaluation of modern advances in geothermal and engineering or science practices, the development and/or implementation of new industries or a resource oriented case study.

This research project should demonstrate how relevant literature, theoretical criteria and considerations, models or concepts raised by the project have been addressed in the project. While it is not expected that major new theories are developed in the project, it is required that the project is to be set in a sound academic, as well as a practical context.

Therefore, concepts or models relevant to each analysis should be reviewed and the most appropriate chosen for application in the project setting. The research therefore covers the theories and methodologies used in conducting the study as well as the main conclusions arrived at. It must be presented in a generic manner without disclosing company details, and should be written to a standard suitable for publication in an academic journal or conference. Its length should normally not exceed 6,000 words including references. Over the years, we have converted tens of these geothermal projects into journal and conference papers.

For students with industry experience, the geothermal project provides the student with the opportunity to apply the scientific and engineering concepts and tools they are exposed to during their PGCertGeothermTech study in a real world environment (generally from their current workplace or industry that they are familiar with and have full access to).

Where a project report contains confidential information, and/or its disclosure could be harmful to the sponsoring company, confidentiality is assured; only the project supervisor and the course coordinator will see such reports.

The projects are aimed at allowing students to develop and apply their new skills gained through the programme, enabling them to experience and reflect on their role as a geothermal engineer or scientist in a practical, real-life context, and giving them the opportunity to demonstrate their newly-acquired technical competencies to their current or future employer.

As demonstrated in Table 2, in recent years, there has been significant changes in student's enrolment trends. While the number of students attending the different geothermal papers/modules has been relatively increasing since 2016. The number of students completing the full PGCert degree has declined (Table 2). This is related to the strong interest in the 120 and 180 interfaculty Master of Energy (taught) program where students carry the credit from doing the geothermal papers toward these degrees.

3.1 Assessment methods in relation to the learning outcome

Assessment methods are the same across the course, and generally take into account the high level of maturity of the students attracted by the programme. Therefore, there is less emphasis on testing of factual knowledge and a stronger focus on application, field studies, case studies and projects. All of the courses are 100% internally assessed, which increases the assessment load on staff, but is very much appreciated by students (see survey).

All papers in the PGCertGeothermTech are assessed internally. This involves 40% course work (including: 10% on field-study reports, 10% for seminars and 20 % on three different assignments). There are 2 tests; a 20% short test (90 minutes long) and 40% final test (three hours long). All the tests are peer reviewed by external industry assessor.

3.2 Teaching methods and the diverse student body

The teaching method is the same across all of the courses; like the assessment methods, they are designed to suit the mature cohort of students, who all have prior practical industry experience.

Students that enrol in the PGCertGeothermTech are generally mature students that have already completed UG degrees and worked in industry for some time; the intensive-paced learning style while completing real world problems is a very good teaching method. Student survey comments have identified that students are happy with this method of study.

All of the students are given a ten-minute individual meeting with the course co-ordinator (myself) to provide the students with feedback and direction. Well-performing students are praised and encouraged to continue to develop and improve. For students that are not performing at an acceptable level; I ask them how they feel about their performance in the programme and what they expect to gain from doing the programme. This makes them realise that their current performance is not satisfactory and that they need to improve. This approach seems to trigger self-motivation without humiliation. Poorly performing students are also engaged through encouragement, direction and offer of help (additional tutorials) if needed, the Head of Department is also notified early in the programme of any poor performing student.

PGCertGeothermTech is a very technical programme with long lecture hours; there is an impact on student attention levels throughout the lectures and it normally drops with time. I regain the student's attention using short technical movies; relevant stories from my field experience or interesting incidents that took place in the industry. We get the students to comment and possibly tell a similar story from their experiences. We also use models of equipment; rock samples and damaged/broken parts of equipment (turbine blades, heat exchangers, drilling bits etc.) as a tool to regain attention; interest and engagement. The students find these additions to the lectures very interesting because it directly relates to their field of work.

3.3 Learning resources

All of the university library information and communications technology, student services are available to the students. Programme specific learning resources vary from course to course, and are generally seen as adequate and of a high quality. Significant material is provided during the lectures and on line and there is also regular interaction and correspondence with the course coordinator via, Tutorials, emails and personal meetings. While the course is postgraduate level, there are daily tutorials covering most of the lectures. This help cement the concepts introduced in the lectures.

Library and IT resources are generally seen as adequate, and support in these areas within the Engineering Faculty has been good. The students are encouraged to attend the orientation programme before the start of the programme.

All the avenues for student support are explained to new PGCertGeoThermTech students at a welcome function at the start of the second semester when the programme begins.

Contingent on the nature of the PGCertGeoThermTech programme and type of students as discussed above, the human resource requirements for administrative and academic support and pastoral care are relatively high compared to other programmes. Currently these factors are seen as adequate by the students, as documented in the responses in the formative feedback survey.

3.4 Graduate profile

Graduates from the geothermal PGCertGeoThermTech programme are confident and competent men and women, well equipped with skills and knowledge to meet the challenges they face in their current and future careers.

Our graduates typically:

• Have a sound grasp of geothermal energy principles and concepts linked to their undergraduate technical background.

• Have well developed critical thinking skills and in-depth knowledge of new concepts from leading research.

• Are able to apply a range of skills, approaches and techniques, compared with untrained staff/professionals working in the geothermal.

• Are very attractive to employers who are looking for professionals who are very passionate about their discipline, and have taken the necessary steps to complement their technical training with a high-quality geothermal qualification.

Depending on their technical background and practical work experience, the knowledge and skills acquired in the PGCertGeoThermTech programme equip our students for a good range of career options within the New Zealand and mainly the international geothermal industries.

Industry feedback has been very good and many of the companies in New Zealand and overseas hire the graduates of the PGCertGeothermTech.

4. PROGRAMME MANAGEMENT, QUALITY ASSURANCE AND ENHANCEMENT

4.1 Programme structure and course selection

Students who enquire by email, or when email is required to provide further information once they have visited the faculty student centre, are directed to the relevant faculty websites page. These pages provide extensive information on each individual programme, including PGCertGeothermTech including:

- Entry requirements
- For international students
- Who should apply?
- Programme outline
- Programme structure
- Courses offered

Information on these pages is backed up with a link to the current online calendar providing confirmation of the regulations that govern the programme.

Admitted students also receive information sheet before arriving New Zealand for the things they will need for the course and mainly for the field trip

4.2 Timetabling and enrolment

Once a student selects a course the information provided to student include;

- course subject and course code
- room location
- duration
- date and time
- related class (if applicable)

- tuition fee

If the student is prevented from enrolling (reasons such as, GPA too low, a timetable clash, course not in approved schedule, permission necessary, or no indication of co or pre-requisite knowledge). The student is given the option of submitting a concession online requiring a student center staff member and the relevant academic to assess the students eligibility (based on assessing the above) to enroll into the concerned course. In order for a student to be enrolled, both the approval of the relevant course and programme convener is required. Once enrolment is approved enrolment into the course is carried out by the relevant staff member from the faculty that 'owns' the course.

5. FUTURE DIRECTIONS

Considering the application and admission statistics in Table 2 above it is clear that currently there is no shortage of interest in the programme. The programme is self-promoted by its international reputation in the geothermal industry and with the "current" New Zealand Government MFAT scholarships.

The staffing and management of the programme has been limited up to 2013, but there has been significant improvement since (2014) with the appointment of a senior lecturer in Geothermal Geology (0.5 FTE), and extra lecturing staff on rolling fixed term contracts.

From my 23 years' experience in the New Zealand and international geothermal industry and as the course coordinator, it is my recommendation to keep student numbers below 35 student/year. This is not only from the UoA's experience since 1979, but also from discussing this with my colleague in Iceland "Mr. Lúdvík S. Georgsson, Director, United Nations University Geothermal Training Programme". There is a much higher health and safety risk associated with taking >35 students into the field. Also given the small size of the geothermal industry, I feel it is not possible to maintain a large (e.g. >40 students/year) stable stream of self-funded students in the long term.

CONCLUSION

The PGCertGeothermTech has been taught for twelve years, from 2007 to 2018 at the University of Auckland. It will continue to be offered in the second semester (July-November) every year. The course is very specialized, with an integrated approach between class-based and field-based education. The course is industry oriented with a strong cross-disciplinary approach to ensure that all students have a grounding of all geothermal-related topics. The success of this approach requires research and field experience on the part of the academic staff, and close co-operation between course teachers and the industry.

In recent years, there has been significant changes in student's enrolment trends. While the number of students attending the different geothermal papers/modules has been relatively increasing, the number of students completing the full PGCertGeothermTech degree has declined (Figure 1). This is related to the strong interest in the interfaculty Master of Energy (taught) program where students carry the credit from doing the geothermal papers toward this degree.

Thanks to the support of the New Zealand Government through the Ministry of Forgan Affairs and Trade (MFAT), New Zealand and International geothermal industry, for supporting students and for contributing to teaching, the course has become established as one of the major geothermal training courses in the world.

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