Bridging theory with real world research experience: Co-teaching Engineering Biotechnology with R&D professionals

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A R T I C L E   I N F O

Article history:
Received 1 March 2016
Received in revised form 5 May 2016
Accepted 7 May 2016
Available online 16 May 2016

Keywords:
Co-teaching
Engineering Biotechnology
Research & development
Industry

A B S T R A C T

This study examined the usefulness of co-teaching with research and development (R&D) professionals to integrate real world research experience into an Engineering Biotechnology course. This research suggests that the need to expose students to post-graduate engineering careers and to prepare them to enter real world engineering is crucial. Two sessions were team-taught by the course lecturer in collaboration with two R&D professionals from local industries. The course lecturer covered the theoretical parts, whereas practicing R&D engineers exposed students to current R&D works. Quantitative and qualitative data on the usefulness of the co-teaching sessions were collected from students and R&D professionals’ surveys, a student interview and peer observation feedback. It was found that bringing R&D professionals into the Engineering Biotechnology class positively impacted on students’ learning. A comparison was also made between the two co-teaching sessions. The evidence showed that managing the lecture and deliverables, and dividing the tasks along the lines of expertise is the key to providing a successful co-teaching session.

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1. Introduction

The new generation of chemical engineers, like their predecessors, will be faced with numerous challenges and will be asked to provide solutions using new and revolutionary tools and technologies (National Academy of Engineering, 2004). With the emerging use of new techniques and technological processes, the role of industrial research and development (R&D) is now seen as critical for the success of any chemical and biochemical industry. This raises the question of what can be expected of new chemical engineers joining the R&D sector of chemical/biotechnical companies? How much knowledge about new applications and novel processes should these students have gained through their university courses? According to Ostrander (2015) it is the responsibility of academia to educate and prepare students in the latest methods being used in industry and to help them understand that the work they do in the classroom is not only important but will also be useful to them in their future employment. Helping students to recognise the relevance of their coursework to their future work in the real world can be viewed as ‘customer service’. Universities have become a globalised part of a service-oriented culture where students are customers and academics are service workers (Macfarlane, 2006; Scott, 1999). Macfarlane (2006) places student service at the base of what he calls the ‘service pyramid’, as he considers this...
to be an important form of academic service. At the next level of the ‘service pyramid’ are collegial service, institutional service, professional service and public service, respectively (Macfarlane, 2006).

Recent studies on engineering education have shown that in order to prepare students to enter real world engineering and to meet these new challenges, the education practice should integrate technical knowledge and skills of both practice and research (Sheppard et al., 2009; Tenenberg, 2011). In other words, to prepare today’s engineers for their future careers, these authors suggest engineering educators and practicing engineers teach together. They further indicated that educating new engineering students about the responsibilities, activities, and projects they may encounter as practicing engineers will have an impact on their desire to continue in engineering (Sable et al., 2014; Traum and Karackattu, 2009).

According to the Washington Accord, which is essentially an international quality mark for engineering education programmes, engineering education should include the least knowledge and provide more opportunities for students to gain experience in industry.

In New Zealand, this view is endorsed and recommended by the Institution of Professional Engineers (IPENZ) and the Institution of Chemical Engineers (IChemE) through their professional accreditation, which requires (i) improved industry-academic links and (ii) the integrated development of key contextual skills and knowledge that underpin professional practice (IChemE, 2011; IPENZ, 2009).

Today, many universities are actively involved in research collaboration with industries. Engineering educators, students and companies are connected through technology transfer, industrial partnerships, student internships and mentoring (Mak, 1995; Watson-Capps and Cech, 2014). At the University of Auckland, New Zealand’s leading research-intensive university, industry and businesses in the engineering sector have significant interactions with the university in providing curricular advice, as guest presenters and workshop facilitators, and in facilitating students to connect with industry through networking and internships. Students, according to the University of Auckland Graduate Profile (2009), are expected to obtain the following general attributes and values by the time they graduate: (i) a mastery of a body of knowledge, including an understanding of conceptual and theoretical elements, in the field of study, (ii) an understanding and appreciation of current issues and debates in the field of study, and (iii) an awareness of international and global dimensions of intellectual, political, and economic activities, and distinctive qualities of Aotearoa/New Zealand. To help students attain these attributes, the University of Auckland is exploring ways to deliver programmes and new pathways in close collaboration with industry.

D’Este and Perkmann (2011) discussed the benefits that faculty members gain from the influx of corporate expertise, and how students gain knowledge about high-throughput technology and commercial applications. Although engineering academics have expertise in teaching and research, they often lack the up-to-date knowledge of industrial practice. Merritt (2001) considers that universities should include new techniques in industrial research in lecture courses, and present them by visiting lecturers able to give an industrial perspective on these issues. Tenenberg (2011) introduces the idea of using ‘industry fellows’, which pairs an industry professional and a university lecturer to co-teach a course. The advantages of this approach are the strengths of each co-teacher in addressing the challenges related to bringing real-world experience into the class. Ostrander (2015) adopted the ‘industry fellow’ model and investigated the impact of the approach on the students, the industry partners, and the lecturer. She found that the co-teaching approach had a significant positive impact on all participants. The students put more time and effort on their projects when an industry partner participated and this resulted in an enhancement in the quality of resulting project (Ostrander, 2015).

The central hypothesis which underlies this study is the connection between the classroom and ‘real world research’ to provide students with the technical and practical information occurring in industry. The hypothesis is based on the premise that students will benefit from being exposed to the additional perspectives that R&D professionals provide and can positively affect students’ motivation to learn as well as recognizing the relevance of their coursework to the real world. In this way, exposing students to R&D practitioners enables them to picture, reflect upon, and make informed decisions about their potential future careers as practicing R&D engineers. Thus, the objective of this study was to investigate the usefulness of integrating real-world R&D practice into the classroom by co-teaching with R&D experts. A study was set up to assess the applicability and usefulness of the co-teaching approach with R&D professionals from the students’ point of view and whether the sessions taught were successful from the peer observers and lecturers’ viewpoints.

2. Methods

2.1. Human research ethics

Approval for the study was obtained from the University of Auckland Human Participants Ethics Committee (UAHPEC).

2.2. R&D partners

It is challenging to find R&D professionals who have the time or the relevant expertise necessary to collaborate in instructing a university course. The R&D biochemical engineering scientists who participated in the co-teaching sessions were from a local industrial R&D company and a research institute. These scientists were selected because of their distinguished domestic and international careers in the areas of industrial and R&D biotechnology, as well as their expertise and professional strengths. The invited R&D professionals have no link to the University of Auckland and are not alumni of the university, although this was not a considered factor at the time and could be an opportunity for further invitations.

The first R&D scientist is from New Zealand Crown Research Institute with expertise in the area of bioreaction engineering including reaction and transport phenomena, bioreactor analysis and process scale up. He has an impressive record of developing innovative technologies and is responsible for leading the research direction for the development of new and emergent environmental biotechnologies in New Zealand. The second R&D scientist is involved in innovation research and from a large and long established New Zealand food company. This R&D professional has expertise and industrial experience in the development and application of innovative technologies in the fields of biotechnology, separation processes and food processing. The university has good relationships with both companies and is already
involved in research collaboration with them. The course lecturer has well-established research collaborations with both R&D professionals. In the first case, the collaboration has been going for more than four years in the area of bioprocessing and hydrothermal treatment of organic and biological waste. In the second case, the collaboration is recently established with strong research connections on the processing of seafood products and the recovery of value-added products from seafood processing by-products. Prior to co-teaching, it was decided that the R&D professionals selected would need to be familiar with the Engineering Biotechnology programme being run so that they understood their role as co-teachers presenting to students.

### 2.3. Co-teaching sessions

Biochemical engineering is both a well-established and a fast growing study and research area at the University of Auckland. Engineering Biotechnology is one of the postgraduate level courses for the qualification of Honours Chemical and Materials Engineering (undergraduate accredited to M level by IChemE) as well as Food Science (postgraduate). This course covers principles of bioreaction and bioprocess technology, enzyme and microbial reaction kinetics, bioreactor design and downstream processing, including oxygen mass transfer in the bioreactors, as well as discussion on selected industrial bioprocess applications. Given the importance of students’ understanding and recognising the relevance of the course materials to the real world research and development work, two co-teaching sessions were designed and integrated into Engineering Biotechnology course.

The normal course consists of twenty lectures with two delivered every week. Each lecture is of two hours duration with a ten-minute break in the middle. There is a team of three lecturers who share the teaching on this course in blocks of about three weeks each but only one lecturer teaches per lecture. In addition to this, students have a laboratory session of six hours duration, in which 3–4 students work in a group to perform one experiment under supervision of a lab demonstrator.

The course lecturer met with each R&D professional several times prior to the sessions to jointly plan the lecture. The sessions were organised to weave together the content, which the course lecturer focused on, with the significant industrial applications and relevant R&D works, which the R&D partner focussed on. Both co-teaching sessions were 2 h in length.

The first session discussed the theory of gas–liquid mass transfer, specifically the transfer and supply of oxygen in fermenters for aerobic culture. The R&D professional contributed to the learning outcomes by explaining the importance of oxygen transfer in aerobic fermentation processes, providing examples of applications, and describing the state of art research relevant to his bioprocessing industry, and pointing out the transport challenges in scale up (Fig. 1). The session began with a group activity to engage the students in the process of learning. The students were requested to discuss the mass-transfer steps involved in the transport of oxygen from the interior of gas bubbles to the site of intermolecular reaction. The course lecturer and the R&D professional both joined in the discussion and answered questions.

The second session discussed the centrifugation technique and its application in the separation and purification of fermentation products in downstream processing. The R&D professional contributed to the learning outcomes by explaining the process function, types of industrial centrifuge machines and equipment selection criteria (Fig. 1).

### 2.4. Data collection

A combination of quantitative and qualitative techniques was used to investigate whether the participation of the R&D partners in co-teaching was beneficial in helping the students to recognise the relevance of the coursework to their future professions in the real world, to assist in their understanding of the subject, and to stimulate their interest in the subject and engagement in the learning process.

Three sets of data were collected: (i) students and R&D professional surveys (quantitative), (ii) a student focus-group interview (qualitative), and (iii) notes from peer observers (qualitative) which together provided feedback on the applicability and usefulness of the approach.

The participation rate for both student surveys was reasonably high (n=44, 60% of the class) as both surveys were scheduled into the class sessions. It should be mentioned that participation in the surveys was optional and therefore the actual class attendance was more than 60%.

Both student and R&D professional surveys consisted of 14 statements, presented in Tables 1 and 2, respectively. In the surveys participants were asked to what level they agreed or disagreed with the statements.

Students who had completed both surveys were invited to participate in a semi-structured focus-group interview, guided by open-ended questions. Ten students, five males and five females, agreed to take up this invitation, which was facilitated by the observer from the Centre for Learning and Research at the University of Auckland. Five of these students were domestic and five were international (n=10, 13.5% of the class). This combination was representative of the class demographics. Open-ended questions were used to allow the participants the opportunity to exchange their experiences and ideas through discussion. While interviewing is a

<table>
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<th>Table 1 – Student survey statements.</th>
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time-consuming process and may be subject to bias and accuracy issues, it allows researchers to follow up ideas, probe responses and investigate motives and attitudes (Baroutian and Kensington-Miller, 2016; Bell, 2010). Prior to interviewing, the student participants were sent the questions, and interviews were audio-recorded. The questions that framed the objectives of this study remained consistent across the interview. The interview began with some general questions regarding the students’ expectations at the beginning of the co-teaching sessions followed by detailed discussions on how useful they found the approach. The audio-recorded interviews were transcribed verbatim by the researchers and reviewed for accuracy.

The peer observations took place during the lecture sessions. As discussed by Weimer et al. (1988) observations by peers can make a significant and valuable contribution to enhance instructional quality.

Peer observation is proven to be of great benefit in reflecting on teaching and can lead to more thinking on what and how things could be improved (Jarzabkowski and Bone, 1998). The two peer observers were senior academic staff from the Department of Chemical and Materials Engineering and the Centre for Learning and Research, at the University of Auckland. The course lecturer and the observers met together prior to the co-teaching sessions to clarify and agree on objectives. Each observer observed one of the co-teaching sessions and made a detailed summary of the process and outcomes of the observation.

### 3. Results and discussion

#### 3.1. The students’ perspectives

For both co-teaching sessions, 44 survey forms were collected and analysed from a class of 74. Overall, as shown in Fig. 2, the students were satisfied with the participation of R&D professionals in the Engineering Biotechnology class. Between 80–90% of the students indicated that the course lecturer and the R&D professionals were well prepared for the sessions. The student survey results were statistically analysed and the results are summarised in Table 3.

From Fig. 2a, approximately 80% of the students found the participation of the R&D professional in the first session was helpful (statement 15) and that they benefited from being exposed to the additional perspectives (statement 7). About 88% of the students indicated that the first R&D professional used real-world examples effectively (statement 12). The survey results also showed that more than 70% of the students agreed that participation of the first R&D professional stimulated their engagement in the learning process (statement 2).
and helped them to recognise the relevance of the coursework to their future work in the real world (statement 6).

Positive written feedback from students included:

- We need this more often and not only in this course.
- Very useful. Often theory does not relate to real-life problems.
- It was interesting to learn about the topic from the perspective of a R&D professional.

These results acknowledge the contribution of the first R&D professional in helping students to understand real-world practice.

After completion of the second session (Fig. 2b), approximately 60% of the students agreed that the participation of the R&D professional was helpful (statement 13). The majority of the students (70%) stated that the second R&D professional used real-world examples effectively (statement 12). However, there was a smaller number of students than before (approximately 50%) who agreed that the participation of the second R&D partner stimulated their engagement in the learning process (statement 2).

The higher number of neutral and disagreement responses in the second session can possibly be attributed to the lack of teaching experience of the second R&D professional. As discussed by Ostrander (2015), industry professionals often do not have the teaching expertise necessary to instruct a course and are unable to bridge the gap between the students and their own level of expertise. Ostrander (2015) also mentions that due to the lack of interactions between industry professionals with teaching academics, there is little opportunity for them to improve their teaching.

The ten students who were interviewed together in a focus group explained that in general the participation of R&D professionals was effective as they enjoyed having an ‘outside voice’ and hearing first-hand about industry. The students felt this addition to the lesson had the potential to make a positive impact on the learning of the course material. The interview focused on the central hypothesis of the study: what was helpful about the participation of the R&D partners. The data revealed that the co-teaching sessions assisted the students to recognise the relevance of the coursework to their future work in the real world:

"The participation of R&D partners was very good, especially the first session was very helpful, to show us why we are learning theories and how we can use it in industry and industrial research." (Student 1)

"Talking about industry was very interesting in the second session, but I think it is more beneficial having academics teach the theories and the R&D partner just talk about their experience." (Student 2)

"The first session was more like a co-teaching but the second session was like a guest lecture." (Student 3)

The interview focused on how participation of R&D professionals assisted students’ understanding of the subject and

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**Table 3 – Statistical analysis for student survey results (n = 44).**

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<th>Term</th>
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<tr>
<td></td>
<td>SA + A (%)</td>
<td>N (%)</td>
<td>D + SD (%)</td>
<td>SA + A (%)</td>
</tr>
<tr>
<td>Mean</td>
<td>74.3</td>
<td>23.1</td>
<td>2.7</td>
<td>59.1</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>11.0</td>
<td>8.6</td>
<td>3.3</td>
<td>12.7</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.8</td>
<td>0.6</td>
<td>0.2</td>
<td>0.9</td>
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SA: strongly agree; A: agree; N: neutral; D: disagree; SD: strongly disagree.
stimulated their interest in the subject. Student 4 reported that he liked the way there was a group activity during the first session, as this included a good interaction with the R&D professional and the course lecturer. Regarding how the integration of real world research experience into the Engineering Biotechnology course can be better implemented, student 1 stated that the R&D professional and the academic should work in a more collaborative way.

3.2. The R&D professionals’ perspectives

The two R&D professionals who participated in the survey commented that their participation in co-teaching the lesson was an excellent experience for them and although they were on unfamiliar ground they enjoyed interacting with the students knowing they were making a contribution to student learning. They considered that the co-teaching approach with an academic was an excellent concept and would be keen to be involved again. The R&D professionals also agreed that such an approach would need testing over a broader range of topics, but their first experiences were very positive.

The results of the survey presented in Fig. 3 show that the two R&D professionals strongly viewed their participations as a service to the community (statement 1). They also viewed their participation as part of an ongoing collaboration with the course lecturer, and the Department of Chemical and Materials Engineering at the University of Auckland (statement 2), which was their initial motivation to participate (statement 4) and hoped it would continue into the future.

Although it was the first time for both R&D professionals to present a formal educational lecture, they treated the opportunity as a way of receiving professional development for themselves (statement 3). Both agreed that their participation helped the students to recognise the relevance of the subject to their future professions in the real world (statement 7).

The first R&D partner commented:

“If the students received some value from me regarding the importance of mass transfer beyond academic walls, that would be great.”

The two R&D professionals agreed that they thought the co-teaching sessions were successful in assisting the students’ understanding of the subject (statement 8). They hoped that their involvement would provide a different angle on the subject, and hence improved understanding.

They understood that their roles were to connect their workplace expertise to student interests and needs (statement 12):

“That was how I viewed the role, entering the lecture. Key was to provide a context for the subject area, to give an idea of the importance of the subject.” (R&D professional 1)

Both professionals reported that they really enjoyed this experience (statement 9), and were both mindful that the students gained some useful insight into the importance of the topics. They considered that an ‘outside voice’ giving a real context might make a positive impact on the learning of the course material. One of the R&D professionals was not very sure if his participation stimulated the students’ interest in the subject (statement 6) or engagement in the learning process (statement 5), and would rely on the feedback to give this.

3.3. Peer observers’ feedback

The first peer observer of the first co-teaching session commented that the course lecturer with the R&D professional appeared well-prepared and that there was obvious agreement between them on the materials to be delivered and by whom. The sequencing of the lecture materials seemed logical and easy to follow. The first peer observer also felt that having a co-teaching partnership broke the monotony especially when the content was demanding or complex. As well, a 2-hour lecture can be exceptionally long so it worked well for the students to see a fresh new face, and this helped with the re-enforcing of ideas during the lecture. The peer observer noted that the involvement of an R&D professional added a new dimension and allowed the students to be exposed to a wider range of viewpoints while highlighting the practical aspects of the theory covered.

Regarding the class activity, the first peer observer stated that it was well-participated and that it was good to see the students confident in seeking points of clarification.

“Going over the practical aspects of the theory just covered in the lecture provided good re-enforcement. The students looked genuinely interested in the activity and interacted with the
lecturer and the R&D professional in discussions before arriving at a solution.” (Peer observer 1)

The first peer observer remarked on the positive side of having a class activity based on the materials just covered in that students are able to see the practical side of what they have been taught while the ideas are still fresh in their minds. The negative side he considered might be that some students may possibly not have had enough time to fully digest the materials covered and therefore might find it difficult to follow.

The second peer observer who observed the second co-teaching session commented that the materials delivered by the second R&D professional, describing the background of the particular industry and how it developed, were effective as they were of interest to the students and presented well. However, the peer observer added that it would have been more constructive if there had been a similar emphasis on where the industry uses the application of centrifugation, the merits and difficulties, so that it enhanced the content delivered by the lecturer. Although the lecturer had specified the areas that the R&D professional was to teach, the second peer observer suggested that to make this work better, the two should have confirmed and coordinated their parts to make sure the lesson flowed. The peer observer also noted the difficulties in co-teaching if R&D professionals did not have any teaching experience and if they did not know the students they were working with. In this case, many of the students were international with little knowledge of the New Zealand context and hence more detail was needed for them.

In general, the two lessons on co-teaching with a professional from industry demonstrated that they were worthwhile and had plenty of merit for future inclusion but needed more cohesion.

4. Conclusions

The need to expose students to post-graduate engineering careers and to prepare them to enter real world engineering is a crucial part of their training. In the chemical industry in particular, especially high-tech industries such as biological and biochemical engineering, the role of industrial research and development (R&D) is critical for future success in these areas. To be able to join the R&D sector, chemical engineering graduates need to have a strong knowledge of the basic principles of their discipline as well as understand the technical and commercial drivers for technology development. The academics involved in teaching the undergraduates have broad expertise in the discipline and teaching but they often struggle with helping students understand that the principles of their discipline will actually be useful to them in their future employment. Collaboration with industry partners or R&D professionals and co-teaching with them can address this challenge. In this study, we reported on a pilot initiative for students enrolled in the Engineering Biotechnology course at the University of Auckland. Two sessions were team-taught by the course lecturer in collaboration with two R&D professionals from local industries. The course lecturer covered the theoretical parts, whereas practicing R&D professional engineers brought a practical side, depicting how the theory tied in with industrial research and development work.

The results showed that integrating real-world R&D practice into the classroom was beneficial for enabling the students to recognise the relevance of their coursework to the real world. Although the data was collected on only two co-teaching sessions, the evidence signalled that the students were satisfied with the participation of R&D professionals in the Engineering Biotechnology class and worth investigating this approach further. The results also showed that managing the lecture and deliverables, and dividing the tasks along the lines of expertise is the key to having a successful co-teaching session. As explained by Ostrander (2015), finding suitable partners can be challenging as well as negotiating the division of labour and balancing the priorities between the partners. In the first session, the students were exposed to a large amount of technical information and learned more about the importance of the subject in process development, whereas in the second session, the students received a good appreciation of the extent of the industry across New Zealand but some students felt less relevant technical details were provided.

Overall, the students and the R&D professionals indicated that the approach was helpful and students were benefited from being exposed to the additional perspectives. It is our recommendation from this study that participation of industry and R&D professionals should be considered as a valuable practice, to be adopted and integrated into Engineering Biotechnology and other chemical and materials engineering courses. Not only do students learn about the latest methods in industry, but also the collaboration between academia and industry increases, bridging the gap between theory and real-world experiences for students.

Acknowledgments

The authors thank the students of 2015 Engineering Biotechnology class for their active participation in this research. The authors gratefully acknowledge Dr. Daniel Gapes (Scion) and Dr. Sabrina Tian (Sanford Ltd). The authors would like to express their gratitude to Professor John Chen of the Department of Chemical and Materials Engineering, the University of Auckland for his invaluable support and advice.

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