Evaluating the development of transferable skills among research engineers in an Industrial Doctorate Centre

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Abstract

In many engineering-based sectors, there is a growing need to foster a new generation of research leaders equipped with skills to drive innovative solutions to so-called 'wicked problems' in society. This need is beginning to shape postgraduate engineering education in the UK, resulting in a growing emphasis on developing students' transferable, professional skills. However, there is a need for improved understanding of how best to assess such skills development. One potential approach has been adopted within STREAM, an Industrial Doctorate Centre focused on training researchers for the UK water sector. One important component of STREAM is the transferable skills and engineering leadership (TSEL) programme. To evaluate the effectiveness of TSEL training, STREAM has adopted a survey tool derived from the Skills Perception Inventory (SKIPI) approach. This tool uses a questionnaire, completed periodically by each student, to explore how research students perceive and evaluate their own skills in key areas. For STREAM engineers, those areas include: research techniques; understanding the research environment; project management; communication; networking and team working; and a number of other sector-specific skills. This paper presents initial results from the implementation of this SKIPI-style tool within STREAM. The findings illustrate the usefulness of the framework in guiding the skills and expertise development of individual students, and in bringing closer alignment between TSEL goals and the delivery of learning experiences. The findings also show how the tool has helped to shape students' understandings of the role of an engineer in the water sector (in terms of what skills are needed).

1 Introduction

Recent evidence suggests that there is a need to revitalise engineering education for the water sector. The recent Cave review on innovation in the water industry in England and Wales re-emphasised the desirability of greater levels of innovation in the sector and confirmed that "in recent years, firms' research and development capacity appears to have declined" (Cave, 2009). This decline in capacity may be attributable, in part, to a worrying deficit of high calibre engineering graduates entering the water sector. Furthermore this deficit may result, not from a lack of engineering students, but from a lack of appropriate skills development among those students – as some have argued that "[g]raduates are often leaving university without the skills and knowledge required to work throughout the water sector" (ICE, 2012).

Alongside these concerns around a deficit of high calibre graduates, the water sector is also facing a severe test of its ability to respond not only to changing expectations of fit-for-purpose solutions (greener, customer driven, cost effective, robust, and future-proof), but also to an ominously ageing asset base, and new requirements to lower carbon footprints (Palmer, 2010). In this context, the sector is re-orienting itself to play a role in the Green Economy, with government being called upon to commit to the development of an appropriate skills pool to underpin both environmental and economic sustainability (CIWEM, 2009). The challenges for the sector have perhaps never been so multi-faceted and immediate, and the need to develop the sector's capacity for research and innovation is increasingly important. Furthermore, there is growing understanding that it is not just technological innovation that's needed, but also more fundamental organisational change (Spiller et. al, 2012). University education, particularly at postgraduate level, is a natural focal point for developing the sector's capacity in these areas, and there is a growing need for degree programmes to help students develop the skills necessary to drive innovation and stimulate change within the sector (McIntosh & Taylor, 2013).

The private sector is also gaining a more prominent role in university education, across many academic disciplines. The recent Wilson review of collaboration between universities and businesses (Wilson, 2012) argued that the UK has the potential to become a world leader in such collaboration. The review recommended that students should be afforded greater opportunities to work directly within industry (e.g. through sandwich years, internships, etc.) and that universities should adopt strategies "to ensure the development and recording of students' employability, enterprise and entrepreneurial skills". The STREAM Industrial Doctorate Centre has adopted both those recommendations in a programme designed to train next-generation engineering research leaders for the water sector.

This paper presents a reflection on the early achievements of the STREAM programme in developing and monitoring key transferable skills among research students. It begins with an overview of the STREAM programme, and then outlines the framework used within the programme to assess students' skills development. The paper then presents some initial results from the skills assessment framework, and discusses the implications of the indicative findings.

2 The STREAM Industrial Doctorate Centre

The STREAM Industrial Doctorate Centre (IDC) (www.stream-idc.net) was established in 2009 with the ambition of providing a vision for industry-led postgraduate training and nurturing a new cadre of research and engineering leaders for the water sector. The centre is comprised of a consortium of five UK universities, and each year it offers 10 studentships for the pursuit of an Engineering Doctorate (EngD). The research projects associated with the studentships are supported by over 20 different water sector organisations, including water companies, consultants, and equipment providers.

To meet its overall ambition, the STREAM programme delivers a subtle balance between industrial and academic contributions. The IDC model is a particularly useful mechanism to achieve this balance, as it supports strong trans-sector cohesion in research and skills acquisition, and delivers specialists with skills in knowledge generation and exploitation as well as crucial experience of working in a professional water sector environment. STREAM therefore aims to provide its students, or research engineers (REs), with an eclectic appreciation of the water

sector's operations, challenges and wider context. The training agenda is informed by sector priorities and refreshed through regular consultation between the universities and non-academic stakeholders.

One of the core components of STREAM is the Transferable Skills & Engineering Leadership (TSEL) programme. The TSEL modules provide REs with specialised guidance on topics such as communication and public engagement, contract negotiation, intellectual property, and the philosophy of science. These modules are designed to increase the breadth of skills development among REs, and are strongly aligned (95% concordance) with the transferable skills priorities advanced by RCUK (2001) and the Engineering Council.

STREAM has experienced some early successes in terms of the quality of graduates attracted to the programme, RE feedback on programme experiences, and industrial satisfaction with the research delivered. These successes have been coupled with a structured consultation and review programme, which has elicited experiences and views from REs, sponsors, and academic staff in order to evaluate programme elements for both impact and value. These reviews have already informed modifications to the induction semester and to the TSEL modules, so that greater emphasis is being placed on leadership mentoring and specialist training provision by independent experts from outside of the five STREAM universities. The reviews have also resulted in changes to how the TSEL programme is assessed, as discussed in the next section.

3 Assessing transferable skills using a SKIPI-style framework

Initial feedback from the first cohort of STREAM students raised some concerns regarding the assessment of TSEL modules. Specifically, there were indications that the TSEL assessments were (i) not commensurate with amount of material delivered, (ii) poorly timed, potentially distracting REs from making progress with their research, and (iii) not always well targeted at learning outcomes. Furthermore, STREAM staff felt that, whilst it was reasonable to expect REs achieve a minimum level of competence on each TSEL topic, it was perhaps unreasonable to expect this competence to be achieved in the same week or the weeks immediately following delivery of the training. Therefore, having a discrete assessment exercise for each module was not considered to be the most effective evaluation mechanism, as it did not allow for the observation of more long-term skills development among REs. It also did not facilitate a more comprehensive assessment of the effectiveness of TSEL training as a whole.

Consequently, the STREAM programme adopted an evaluation tool derived from the Skills Perception Inventory (SKIPI) framework proposed by Alpay and Walsh (2008). The SKIPI approach uses a combination of questionnaires and interviews to explore how research students perceive and evaluate their own skill levels in key areas. Based on this overall approach, a bespoke questionnaire was developed for STREAM, to be completed periodically by each RE. Eight key skills groups were proposed: (A) research skills; (B) understanding the research environment; (C) research project management; (D) personal effectiveness; (E) communication skills; (F) networking and team working; (G) career management; and (H &I) sector-specific skills. Within each skills group, up to 9 specific behaviours were described. When completing the questionaire, students were asked to rate their confidence in their ability to accomplish each behaviour, on a scale of 1 to 7 (1 meaning not confident, and 7 meaning very confident in their ability). A total of 45 specific behaviours were included in the questionnaire.

For the STREAM programme, the SKIPI approach offered a number of practical advantages – for instance, it could be administered remotely, which made it much easier for REs to complete (as many of them are based in different parts of the country). Additionally, because the REs could complete the survey in their own time, it interfered far less with the rest of their research activities. Most importantly, the evaluation tool (i.e. the questionnaire) could be tailored much more specifically to gauging the intended learning outcomes of TSEL modules, and it offered considerable promise in facilitating longitudinal analyses – both of the TSEL programme as a whole, and the skills development progress of individual students.

The questionnaire was first administered within the STREAM programme in 2010, and was repeated in 2012. For the purposes of this study, we selected and analysed the survey results from 17 REs who had completed the survey in both years. Informal interviews with those REs also helped to gather their impressions of their progress in the various skill areas, as well as their thoughts on the tool itself. The aim of this study is to provide some early reflections on the usefulness and the impacts of the STREAM questionnaire, and the SKIPI approach in general, as a means of evaluating and informing skills development.

4 Early experiences from the application of SKIPI within STREAM

An overview of initial results from the questionnaire is presented in Table 1. The limited sample size for this study precludes much of the kind of substantive statistical analyses that have characterised some previous applications of SKIPI frameworks (e.g. in Alpay & Walsh, 2008). However, the average scores presented in Table 1 do highlight some indicative findings.

For instance, the average scores for every skills group appear to show an overall increase in confidence between 2010 and 2012. However, the differences are generally quite small. When the average scores for specific behaviours are examined, in general this improvement in confidence becomes less apparent. Few of the specific behaviours show marked increases in average scores – indeed, for some specific behaviours (e.g. A1, B2, C4) the scores have even dropped slightly. Worryingly, some of the specific behaviours with particularly weak average scores have shown little (if any) improvement in student confidence (e.g. B2, F1, H1). However, some marked improvements in average scores are also noticeable, and these are highlighted in the table. For instance, the specific behaviour which showed the largest increase in average confidence scores was E5 (‘Supervise and MSc student research project’) followed closely by H6 (‘Negotiate the conditions of a research contract’).

Discussions with REs themselves also echoed these findings to some degree. All of those interviewed felt that their confidence in their abilities had generally improved across the different skills areas. When asked if there were any specific behaviours for which their confidence had not improved, the ones that were most often mentioned were E4 (‘Present the key features of your work to a class of 10 year old children’), H1 (‘Explain the ontological and epistemological foundations of your research approach’), and I1 (‘Define in legal terms "bullying" "harassment" and "discriminatory behaviour"… etc.’). These responses are reflected in the consistently weak average scores for those specific behaviours.

Table 1 – SKIPI survey results from 17 research engineers in 2010 and 2012

	Skills	Average scores (1-7)		Difference 2010-2012	Average scores within skills group (1-7)	
		2010	2012		2010	2012
A1	Develop both hypotheses and answerable research questions from a given problem context	5.06	4.82	-0.24	4.33	4.78
A2	Discuss and debate theoretical concepts in your domain and propose new directions for your research	4.29	5.06	0.76		
A3	Summarise how thinking in your field has changed and evolved over the past 10 years	4.12	4.65	0.53		
A4	Articulate the difference between "techniques", "methods" and "methodology"	3.82	4.12	0.29		
A5	Defend your research methods and findings in front of a panel of experts in the field	4.12	4.88	0.76		
A6	Provide a chronological history of your research activities and relate it to how your thinking on the research problem has developed	4.59	5.18	0.59		
B1	Identify three pieces of legislation or regulation which are driving research expenditure in your field	4.35	4.94	0.59	4.00	4.29
B2	Prepare a submission to an ethical research review committee for a research activity involving human subjects OR prepare and submit a database for registration under the Data Protection Act	3.00	2.76	-0.24		
B3	Lead a seminar on "What it means to behave professionally" OR on "Health & Safety issues" OR on "Duty of care and responsible practice"?	3.53	3.65	0.12		
B4	Specify the key components of a good research proposal	4.18	4.59	0.41		
B5	Defend the choices you have made about method and experimental techniques and identify the limits to generalisation of your research findings	4.71	5.00	0.29		
B6	Prepare and deliver a business case for further investment in your research based on the outcomes to date	4.24	4.82	0.59		
C1	List and prioritise your research goals for the next week the next month and the next six months?	4.94	5.82	0.88	4.87	5.29
C2	Design a literature search strategy for a research topic you are not familiar with	4.53	5.06	0.53		
C3	Access published papers which are not available through the normal online databases	4.71	5.35	0.65		
C4	Continue with your work if your laptop or desktop computer crashed and all the data was lost	5.29	4.94	-0.35		
D1	Deliver a lecture or conference presentation on a subject unconnected to your field of research	3.41	3.47	0.06	4.93	5.14
D2	Develop new research methods or adapt existing methods	4.24	5.06	0.82		
D3	Revise your research programme in the light of comments from supervisors	5.47	5.59	0.12		
D4	Identify deficiencies in your own skills and competencies profile	5.00	5.29	0.29		
D5	Work effectively to deadlines	5.53	5.47	-0.06		

D6	Identify sources of help and support within your work and study environment	5.59	5.71	0.12		
D7	Take autonomous decisions regarding the day to day running of your research	5.29	5.41	0.12		
E1	Identify the features of a good academic paper	4.24	5.06	0.82		
E2	Participate in a round table debate at a public enquiry on a topic linked to your research	4.24	4.76	0.53		
E3	Present your work via a podium presentation at a major academic conference	3.82	4.47	0.65	4.13	4.75
E4	Present the key features of your work to a class of 10 year old children	4.71	4.53	-0.18		
E5	Supervise an MSc student research project	3.65	4.94	**1.29**		
F1	Identify five people who you could talk to about funding the next stage of your research and five researchers from other countries who you have spoken to in detail about your research	2.59	2.65	0.06		
F2	List those aspects of your personal character which make you easy or difficult to work with in a team	5.18	5.18	0.00	4.41	4.53
F3	Receive feedback and deal with criticism of your work	5.47	5.76	0.29		
G1	Specify what development you require in order to obtain your career ambitions and describe what interpersonal and management skills you need to develop	4.88	4.88	0.00		
G2	Specify an idealised career path for yourself and prioritise your own training and education needs	4.88	4.82	-0.06	4.50	4.68
G3	Identify which transferable skills would be important in a research and in a commercial environment	4.65	5.06	0.41		
G4	Apply for a job as an Innovation Manager in a UK water utility or a post doc at a university	3.59	3.94	0.35		
H1	Explain the ontological and epistemological foundations of your research approach	2.65	3.24	0.59		
H2	Initiate organise lead and deliver the outcomes of a business meeting	4.12	4.53	0.41		
H3	Explain the role of engineering and engineers in society	4.76	4.65	-0.12		
H4	Prepare a full cost/benefit appraisal for a research activity	3.94	4.29	0.35		
H5	Prepare a business risk case for implementation of a new technology process or method	3.41	4.41	**1.00**	3.75	4.30
H6	Negotiate the conditions of a research contract (acting for the client or provider)	2.94	4.19	**1.25**		
H7	Serve on the interview panel for a new appointment to your department	3.69	4.00	0.31		
H8	Lead a seminar debate with students and academics on your research topic	3.81	4.44	0.63		
H9	Write an article for publication in a trade magazine read by professionals who may be interested in your research	4.44	4.94	0.50		
I1	Define in legal terms "bullying" "harassment" and "discriminatory behaviour" and describe your legal responsibilities in respect to these in your interactions with your colleagues other students and those you engage in your research	3.63	3.69	0.06	N/A	

When asked if there were any specific behaviours for which their confidence had improved significantly, responses were much more varied. However, there was often emphasis on the importance of 'learning by doing' – for instance, several REs described how their confidence in supervising an MSc student (E5) was dependant on having opportunities to do so (independent of any training on the subject). Similar links were made in regard to communication behaviours such as giving conference presentations (D1), as well as organisational ones such as prioritising research goals (C1). Some responses also highlighted that opportunities for skills development could extend beyond the STREAM programme itself – for instance, one RE indicated that her confidence in some skills had improved through undertaking non-STREAM doctoral training courses offered by the university.

Finally, it is worth noting that REs often spoke of their initial surprise, when they first completed the questionnaire, at the breadth of specific behaviours included within it, and how some of the behaviours were therefore 'intimidating'. The behaviours that elicited such surprise and trepidation were often communication-related (such as E2: 'Participate in a roundtable debate at a public enquiry on a topic linked to your research'). These kinds of responses indicate that the questionnaire itself could serve as a useful signpost for REs, helping to shape their understanding of what skills and behaviours are important for research engineers in the sector.

5 Discussion & Conclusions

This preliminary study of skills assessment using a SKIPI-style framework has revealed several advantages, as well as some challenges. One of the key advantages is that the questionnaire permits the identification of specific skills where progress has been good (i.e. those where the scores increased markedly) and where progress has been lacking (i.e. those where the scores have remained weak). For the latter skills, there is perhaps a need to revisit how relevant training is delivered, and whether/how REs might be given opportunities to develop and utilise those skills further.

Another advantage of the STREAM SKIPI framework is that it captures the breadth of skills development opportunities that are available to students, rather than focusing exclusively on the impacts of specific training modules (which was the focus for Alpay & Walsh, 2008). This is particularly important since, as RE responses highlighted, many improvements in confidence were associated with experiences outside of TSEL training. This does not negate the importance of the TSEL modules, but rather provides universities with a means of understanding and potentially maximising the synergies between different skills development opportunities. In a similar vein, the framework also has considerable potential as a tool for longitudinal analyses of skills development within particular cohorts of students.

Finally, the findings showed that SKIPI approaches have considerable potential in motivating skills development of students. Not only can it broaden students' perceptions of what skills are important, it can also act to reinforce improved confidence. For instance, one RE described how, in completing the questionnaire for the second time, she became aware of how her confidence had improved across most of the skill areas, which gave her further motivation to develop her skills further.

One challenge for these kinds of SKIPI approaches is understanding how students apply the scoring metric (e.g. whether it's clear to them) and to what extent they can apply it consistently when repeating the questionnaires. For STREAM, this is particularly challenging because REs

often complete the questionnaire remotely (with limited guidance), and because there is a considerable time lag between questionnaires. For instance, several REs indicated that, when they completed the questionnaire in 2012, they had little memory of the one from 2010, which may significantly decrease the likelihood that they will apply the scoring system consistently. Understanding how the scoring system is applied is important for assessing whether changes in scores for particular behaviours are actually reflective of changes in perceived abilities.

One of the most important questions for SKIPI approaches, which this study has not been able to address in any detail, is whether the 'right' skills are being assessed. In other words, are the specific behaviours included in the STREAM questionnaire the most effective indicators of the skills that are needed for new research engineers entering the water sector? In this regard, the survey may benefit from some revision in line with the 'T-shaped water professional' model recently proposed by McIntosh and Taylor (2013). That model focuses specifically on unpacking the competencies of leadership in the water sector, which the authors argue is essential for driving innovation and change. This model may therefore be useful in developing specific, leadership-oriented behaviours that could be included within the questionnaire.

Overall, these initial findings suggest that this SKIPI-style evaluation is becoming an effective tool to assess, and help develop, key transferable skills among REs in the water sector.

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