Project No.: 244749

Project Acronym: ESTABLISH

Project Title: European Science and Technology in Action: Building Links with Industry, Schools and Home

Work Package 5 | Deliverable 5

D5.5 Report on the final profile of pre-service science teachers' attitude and understanding of IBSE

Dissemination Level: Public

Thematic Priority: Science in Society

Funding Scheme: Coordination and Support Actions

Deliverable No.: D5.5

Due date of deliverable: January 2014

Actual submission date: 21/03/2014

Start date of project: 01/01/2010 Duration: 51 months

Name of Coordinator: Dr. Eilish McLoughlin

Name of lead partner for this deliverable: DCU

TOTAL NUMBER OF PAGES: 55

A. Background to this report

This report is a deliverable of Work Package 5 (WP5) of the European FP7-funded project "European Science and Technology in Action: Building Links with Industry, Schools and Home" (ESTABLISH; 244749, 2010-2013). It meets the requirements of the Deliverable 5.5 by presenting a report on the final profile of pre-service teachers' understanding of and attitude to inquiry based science education.

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This document, published in March 2014, has been produced within the scope of the ESTABLISH Project, which has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 244749.

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B. The ESTABLISH consortium

Beneficiary short name	Beneficiary name	Country	Abbreviation
DCU	DUBLIN CITY UNIVERSITY	Ireland	IE
AGES	AG EDUCATION SERVICES	Ireland	IE
UmU	UMEA UNIVERSITET	Sweden	SE
JU	UNIWERSYTET JAGIELLONSKI	Poland	PL
CUNI	UNIVERZITA KARLOVA V PRAZE	Czech Republic	CZ
AL	ACROSSLIMITS LIMITED	Malta	MT
UPJS	UNIVERZITA PAVLA JOZEFA ŠAFÁRIKA V KOŠICIACH	Slovakia	SK
UTARTU	TARTU ULIKOOL	Estonia	EE
UNIPA	UNIVERSITA DEGLI STUDI DI PALERMO	Italy	IT
MaH	MALMÖ UNIVERSITY	Sweden	SE
IPN	LEIBNIZ-INSTITUT FUER DIE PAEDAGOGIK DER NATURWISSENSCHAFTEN UND MATHEMATIK AN DER UNIVERSITAT KIEL	Germany	DE
CMA	CENTRE FOR MICROCOMPUTER APPLICATIONS	Netherlands	NL
MLU	MARTIN LUTHER UNIVERSITAET HALLE-WITTENBERG	Germany	DE
FU	Frederick University	Cyprus	CY

D5.5 Final Profile of pre-service science teachers' attitudes and understanding of IBSE

Contents

EXECUTIVE SUMMARY

Pre-service teachers were introduced to inquiry based science education (IBSE) through resources and materials developed within the ESTABLISH project. The pre-service teachers who attended the ESTABLISH teacher education programme (TEP) were asked to complete two questionnaires, one at the start of the TEP and the other after the TEP was completed. The data has been analysed to determine the following attributes of the teachers in relation to the initial profile of the teachers and also to determine the change that occurs after completing the TEP:

- Understanding of inquiry
- Attitude towards inquiry
- Industrial importance/links
- Practice in the inquiry classroom
- Personal Skills in relation to inquiry

The profile of these pre-service teachers are that approximately 70% of the group were aged under 25 years, had less than 20 weeks teaching experience and 65% were female. The pre-service teachers rated themselves on the basis of their experience with inquiry based science education as 59% beginners (BE), with 33% some experience (SE) and 1% very experienced (VE). It is not clear if those with some experience of inquiry experienced inquiry as a student or if they actually taught through inquiry.

While the group of pre-service teachers were from 8 different institutions across Europe, they were similar in a number of aspects. Their understanding of inquiry and of the roles of the teacher and student in the inquiry classroom was greater in those with some experience than the beginners group. Their attitudes to IBSE were mainly positive with over 50% of the beginners and nearly 70% of those with some experience stating that they felt that inquiry was appropriate to achieving the aims of the curriculum and that it was suitable for all students.

The majority of the pre-service teachers are also quite positive towards the Industrial Links, with over 80% of teachers (both beginners and some experienced) agreeing that good teachers help students understand the importance of science and technology for our society. Also over half of the some experienced teachers feel that they have sufficient knowledge of science to implement an inquiry lesson effectively, compared to just a third of beginners teachers.

The change in these attributes after using the ESTABLISH materials have been determined. As these are pre-service teachers who are attending teacher training programmes, they are developing the skills and knowledge that they need in their role as a teacher. Large changes are therefore not expected, as the programme is short relative to their training.

After the programme, the beginners group have increased their understanding of inquiry and the roles of the teacher and student in the inquiry classroom; they have also shifted towards more positive attitudes to inquiry. There was little change in those with some experience in relation to their understanding of inquiry.

While both groups of pre-service teachers shift towards agreeing that they could easily relate science concepts in the curriculum beyond the classroom, they were uncertain that they show students the relevance of science in industry and if their students understand the importance of science and technology in our society.

The skills necessary to implement inquiry within the classroom are increased in the pre-service teachers with some experience of inquiry as they become more confident of asking higher order questions and of having sufficient knowledge of science to enable inquiry in the classroom. The experience level of the pre-service teacher and the cohort in which they are in seem to be more important factors in determining their understanding and attitudes, rather than their gender. While small differences were determined based on gender differences, the sample size is too small to make definitive statements on gender effects.

Clearly the ESTABLISH pre-service programme has increased the understanding and attitudes of these pre-service teachers and has encouraged them to think about role of industry in teaching and role of inquiry within the curriculum.

INTRODUCTION

The ESTABLISH project focusses on developing and implementing education programmes for teachers (TEP), where the participants can increase their knowledge of and implementation skills of inquiry based teaching. In the teacher education programmes for pre-service teachers, ESTABLISH partners used many of the resources and materials developed within the project and adapted the In-service TEP for use with the pre-service group. The In-service TEP has 4 core elements, namely Inquiry and what it is, Industrial links in inquiry, Teacher as implementer of inquiry and Teacher as developer of inquiry. These were incorporated into pre-service programmes as discussed in D5.6.

To determine the changes these initiatives have on pre-service teachers in terms of their understanding and attitudes towards inquiry, an evaluation tool was developed to determine the teacher's attitudes at the beginning and after the programme. Specific focus is placed on the change in teacher's attitudes towards inquiry, their understanding of the relevance of industrial links and their understanding of inquiry. Cognisance was taken of any gender effects also.

BACKGROUND

An evaluation tool was developed in the form of a paper questionnaire, which was distributed to pre-service teachers at the beginning of the TEP programme. A second questionnaire was distributed to the same pre-service teachers either at the end of the series of workshops or some months after completion of the TEP. Each country had different structures for the implementation of the Inquiry course for the pre-service teachers and these are discussed in D5.6.

This document discusses the changes that are evident in the responses to the questionnaires, comparing responses at the beginning of the programme and after the TEP. The report is structured into four sections, where Section 1 presents an overview of the cohort of pre-service teachers and profiles them based on their country and on their experience level in terms of inquiry teaching. Section 2 outlines the changes that have occurred as a result of the ESTABLISH TEP. Within Section 3, any gender effects are highlighted and discussed while Section 4 details the methodology used in analysing the data.

The data has been analysed to determine the following attributes of the teachers:

- Understanding of inquiry
- Attitude towards inquiry
- Industrial importance/links
- Practice in the inquiry classroom
- Personal Skills in relation to inquiry

SECTION 1 Overview of teacher sample

1.1 Overview

In total 367 pre-service teachers from 8 institutions completed the first questionnaire. Throughout this report, the pre-service teachers will be considered 'teachers', and so the term 'teachers' implies 'pre-service' teachers throughout.

The overall sample shows a narrow spread of age, teaching experience and experience with inquiry based science education (IBSE). Table 1 gives an overview of the teacher cohort. Approximately 70% of the group were aged less than 25 years and roughly 65% were female. In most cases, female teachers outnumbered male teachers, with the exception of three cohorts, A, H and K. In terms of teaching experience, three quarters of the overall group had 0-20 weeks of teaching experience.

In completing the questionnaires, the teachers rated themselves as being a beginner (BE) in terms of IBSE, or if they had some experience (SE) or were very experienced (VE). Using this rating, the overall cohort consisted of 59% BE, 33% SE and 1% VE teachers. The SE group have individuals from each cohort, except H. The majority of the BE group comes from three cohorts B, C and D. Interestingly, even though more than 80% of the cohort had less than 20 weeks of teaching experience, 32% claimed to have some experience with inquiry teaching (Figure 1).

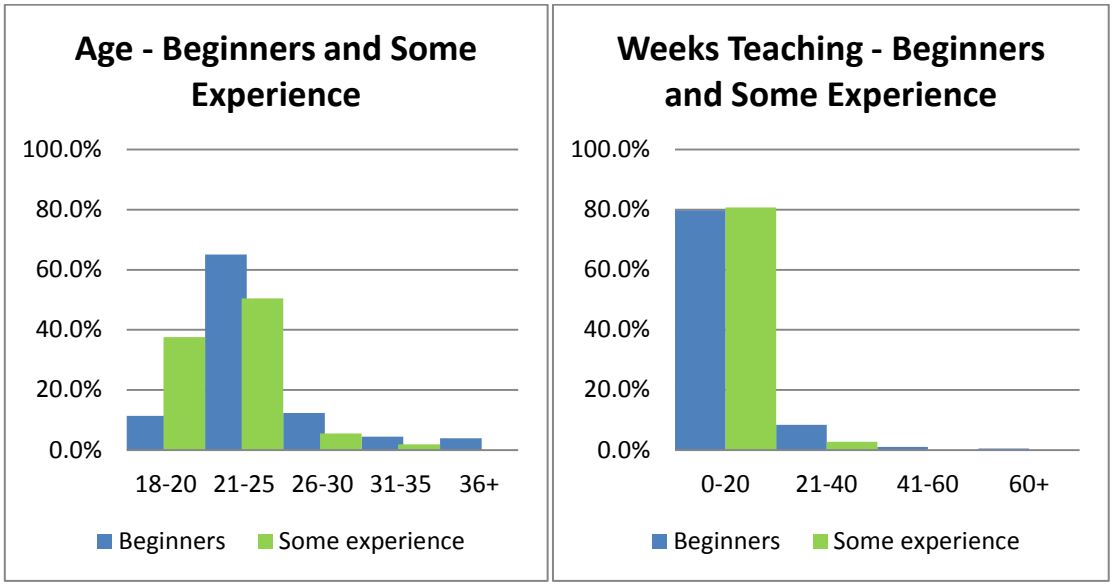

Figure 1: Age distribution and weeks teaching experience for those rated (a) Beginners, (b) Some Experience

Partner	Code	Number of Teachers	Age range %*					Weeks teaching %*						Gender %*		Experience with IBSE %*			Matched Pre & Post
			18-20	21-25	26-30	31-35	36+	0-20	21-40	41-60	61-80	81-100	101+	M	F	BE	SE	VE	
CMA	**H**	25	-	-	-	-	-	-	-	-	-	-	-	68	32	-	-	-	0
CU	**B**	48	-	88	13	-	-	92	4	-	-	-	-	29	71	83	17	-	90
DCU	**A**	83	74	12	2	-	-	100	-	-	-	-	-	54	46	37	61	-	40
IPN	**J**	50	4	74	18	4	-	38	-	-	-	-	-	24	76	60	38	-	52
JU	**D**	59	2	98	-	-	-	98	-	-	-	-	-	10	90	93	7	-	56
MLU	**K**	26	8	69	23	-	-	77	-	-	-	-	4	58	42	54	42	4	23
UN	**C**	40	3	25	28	23	20	44	46	5	-	-	2	43	58	93	5	3	100
UP	**E**	36	-	92	8	-	-	100	-	-	-	-	-	8	92	28	69	-	100
Total	**Total**	367	18	57	10	3	2	76	6	1	-	-	0.3	35	65	59	33	1	59

Table 1: Overview of teacher cohorts that have completed questionnaires * Balance relates to percentage of non-respondents.

1.2 Profile of teachers

The data from the questionnaires was coded and analysed by cluster analysis, i.e. multidimensional scaling (MDS). MDS was used to focus on the individual cohorts and, in this section, to examine similarities and differences between different cohorts of teachers; in Section 2, the changes in each cohort following the ESTABLISH programme is analysed by MDS. MDS is an analysis technique that graphically displays dissimilarities / similarities among objects. Objects that are considered similar to each other are represented by points that are close together on the MDS plot. This is further explained in Section 4.

1.2.1 Understanding of inquiry

Teachers' overall understanding of inquiry is determined from their responses to questions asking them to rate their understanding of IBSE, as well as their understanding of the role of a teacher and the role of the students in the inquiry classroom. The distribution of the responses based on each teacher cohort is analysed by MDS and mapped relative to an 'ideal' response (Figure 2). The 'ideal' response is that of fully understanding IBSE and the roles of teacher and student in an inquiry classroom.

From Figure 2, it is clear that cohorts divide into 2 clusters with one outlier, Cohort C. Cluster 1 (cohorts K, B, D and J) are mainly beginners with inquiry, and all of these cohorts have between 53% and 94% BE. Cohort C is also mainly BE teachers. Cluster 2, (cohorts A and E), have over 60% with some experience with inquiry.

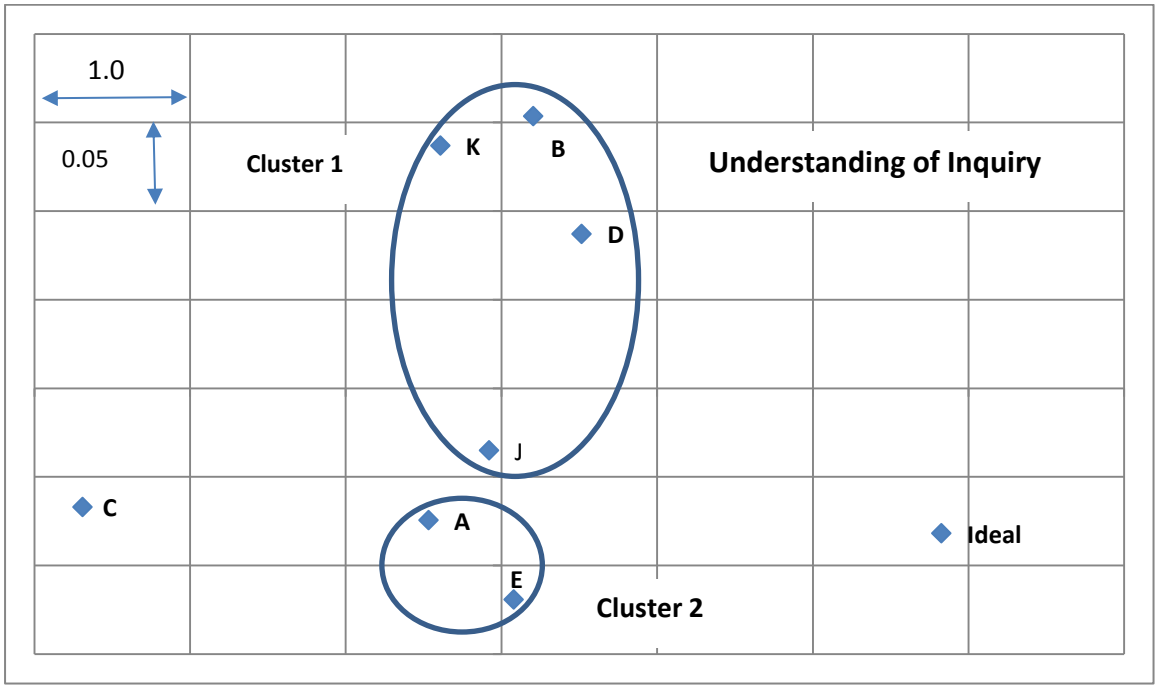

Figure 2: MDS diagram for Understanding of Inquiry, based on initial profile

Therefore some of the variation between teacher cohorts may be accountable by the difference in levels of experience of the individual teachers within the cohort. The individual response to each question, based on their level of experience, is shown in Figure 3. Most of the SE teachers understand inquiry and the role of teacher and students in an inquiry classroom. However, more of the BE group (70%) understand the role of the student in the inquiry based classroom but only 58% understand inquiry instruction (see Figure 3 and Table A1.1 in Appendix).

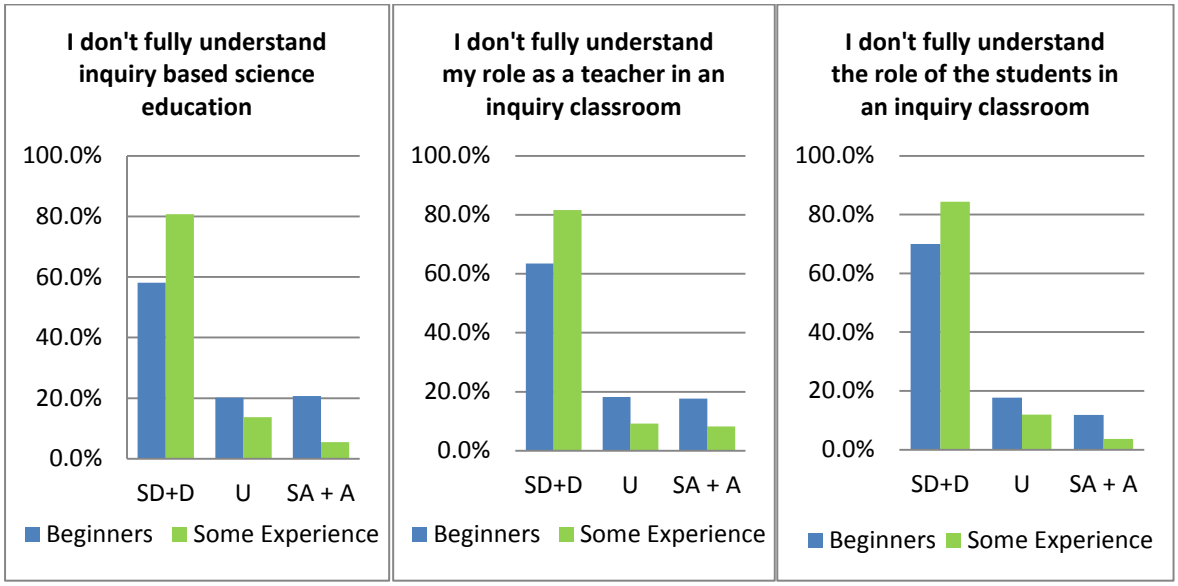

Figure 3: Responses to questions relating to Understanding of Inquiry, based on individual teacher experience in IBSE (SD +D, U, SA + A = strongly disagree and disagree, uncertain, strongly agree and agree) Balance to 100% relates to percentage of non-respondents

1.2.2 Attitude towards inquiry

Barriers to implementing inquiry practices in the classroom have been noted from the literature to include lack of classroom time, lack of 'good ' students and lack of relevance to the curriculum. Teachers' level of agreement to the following three statements were combined to give an indication of the teachers' attitudes to inquiry:

- I think inquiry takes up too much classroom time for me to implement;
- The use of inquiry is appropriate to achieving the aims of the curriculum;
- Inquiry based teaching is only suitable for very capable students.

An 'ideal' response to these questions would indicate strong agreement that inquiry does not take too much classroom time to implement, that inquiry is appropriate to achieving the aims of the curriculum and is also suitable for all students.

MDS analysis (Figure 4) indicates that two clusters of teacher cohorts are evident. Both clusters are a distance away from the ideal response. Overall, the participants in cluster 1 (B, D, J and K) disagreed more with the statements "I think inquiry takes up too much classroom time for me to implement" and "Inquiry based teaching is only suitable for very capable students" than cluster 2 (A, C and E). However, the participants in cluster 2 were slightly more in agreement with the statement "The use of inquiry is appropriate to achieving the aims of the curriculum", than cluster 1.

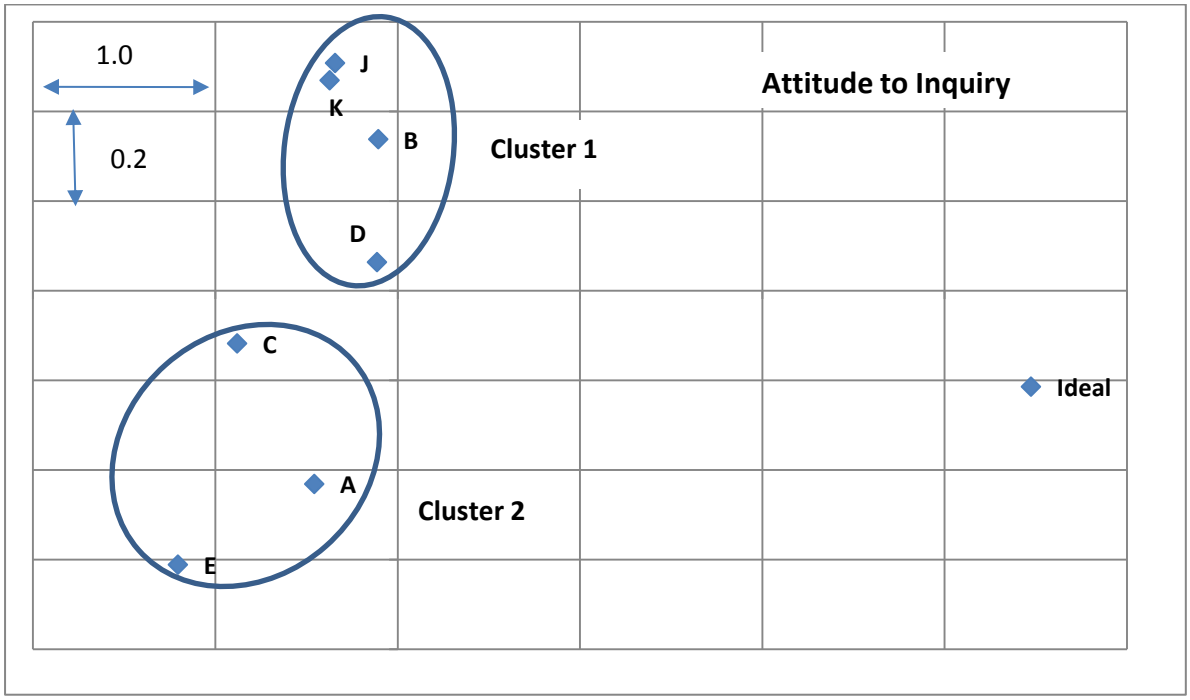

Figure 4: MDS diagram for Attitude to Inquiry, based on initial profile

Further analysing the data based on teacher experience level shows small differences (see Figure 5). Those with SE are more in agreement that inquiry is appropriate to achieve the aims of the curriculum and interestingly, both the BE and SE group are favouring inquiry for all students. Over a third of the BE and SE cohorts indicate that inquiry does not take up too much classroom time to implement.

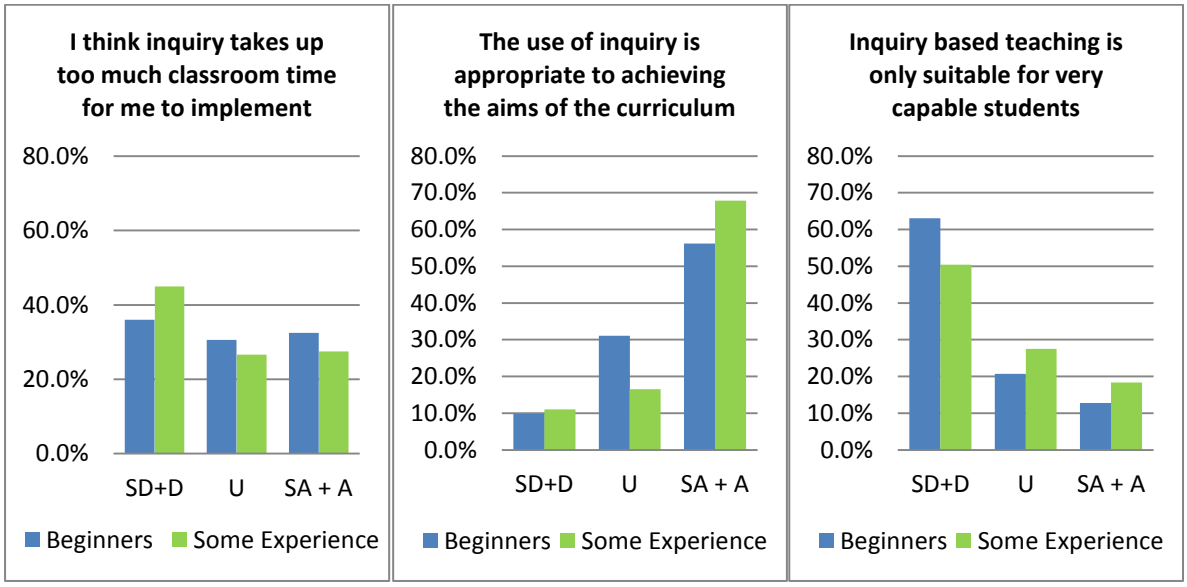

Figure 5: Responses to questions relating to Attitude to Inquiry, based on individual teacher experience in IBSE (SD + D, U, SA + A = strongly disagree and disagree, uncertain, strongly agree and agree) Balance to 100% relates to percentage of non-respondents

1.2.3 Industrial Links

Being aware of the context of science in the wider world and the applications of science and bringing these into the classroom can really enrich the experience for the students. A key objective for ESTABLISH was to promote the context and applications of science within industry in the classroom and to broaden the definition of industry. Several questions were asked to determine teacher responses to the extended view of science in their classroom. The 'ideal' response was categorised as strong agreement with each of the statements:

- I want my students to know about the latest developments and applications of science and engineering;
- I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom;
- Good teachers show students the relevance of science in industry;
- Good teachers help students understand the importance of science and technology for our society;
- If I had more information about industrial processes, I would use it in my teaching.

The MDS analysis for all the teacher cohorts is shown in Figure 6. MDS analysis shows a cluster of cohorts approximately equidistant from the ideal (A, B, D, J, and K). Cohorts C and E are both outliers here. Overall, of the 5 statements presented to the teachers, Cohort C agreed more strongly with the statements "I want my students to know about the latest developments and applications of science and engineering" and "I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom" than the participants in cluster 1. The other outlier, cohort E, was more uncertain about all of the statements in this category than the other cohorts.

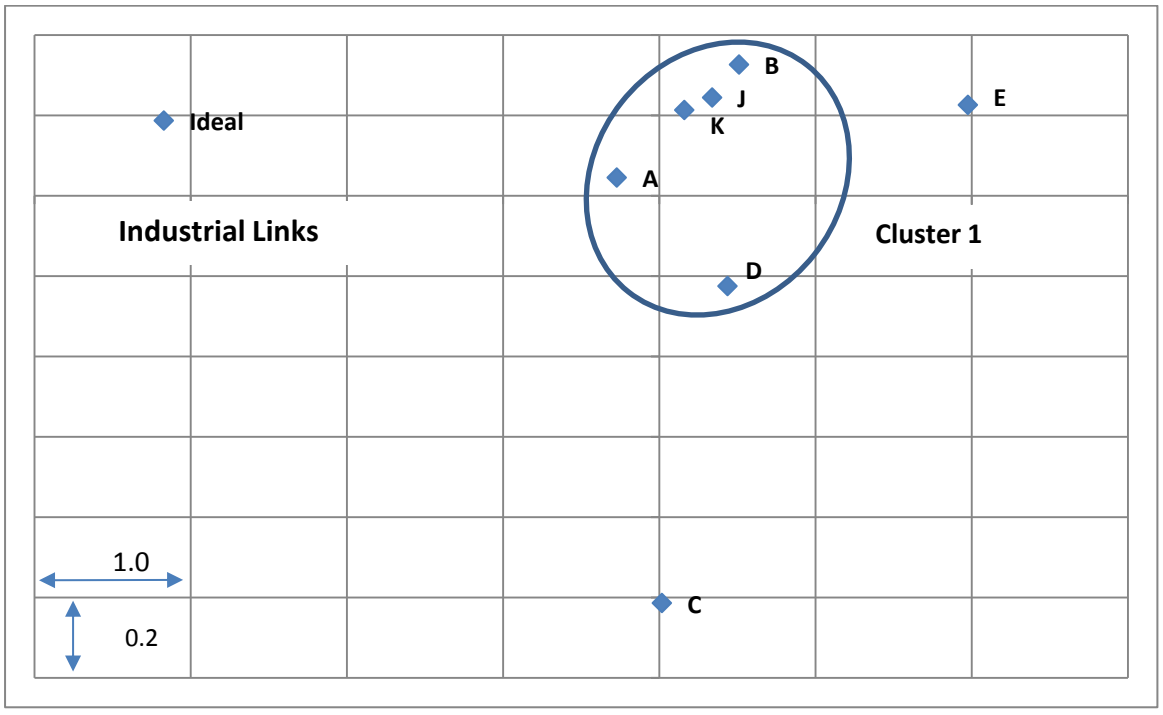

Figure 6: MDS diagram for Industrial Links, based on initial profile

Within this section, there is little variation based on experience level. Across all the questions, there is good agreement by all teachers to the statements given, indicating that the majority of teachers value a broader view of science in the classroom, with over 90% of the BE teachers and 80% of the SE teachers stating that they agree that "Good teachers help students understand the importance of science and technology for our society" (Figure 7 and Table A1.3 in Appendix). While most of the BE and SE groups would use more information about industrial processes in their teaching, approximately a third of the BE group are uncertain of this.

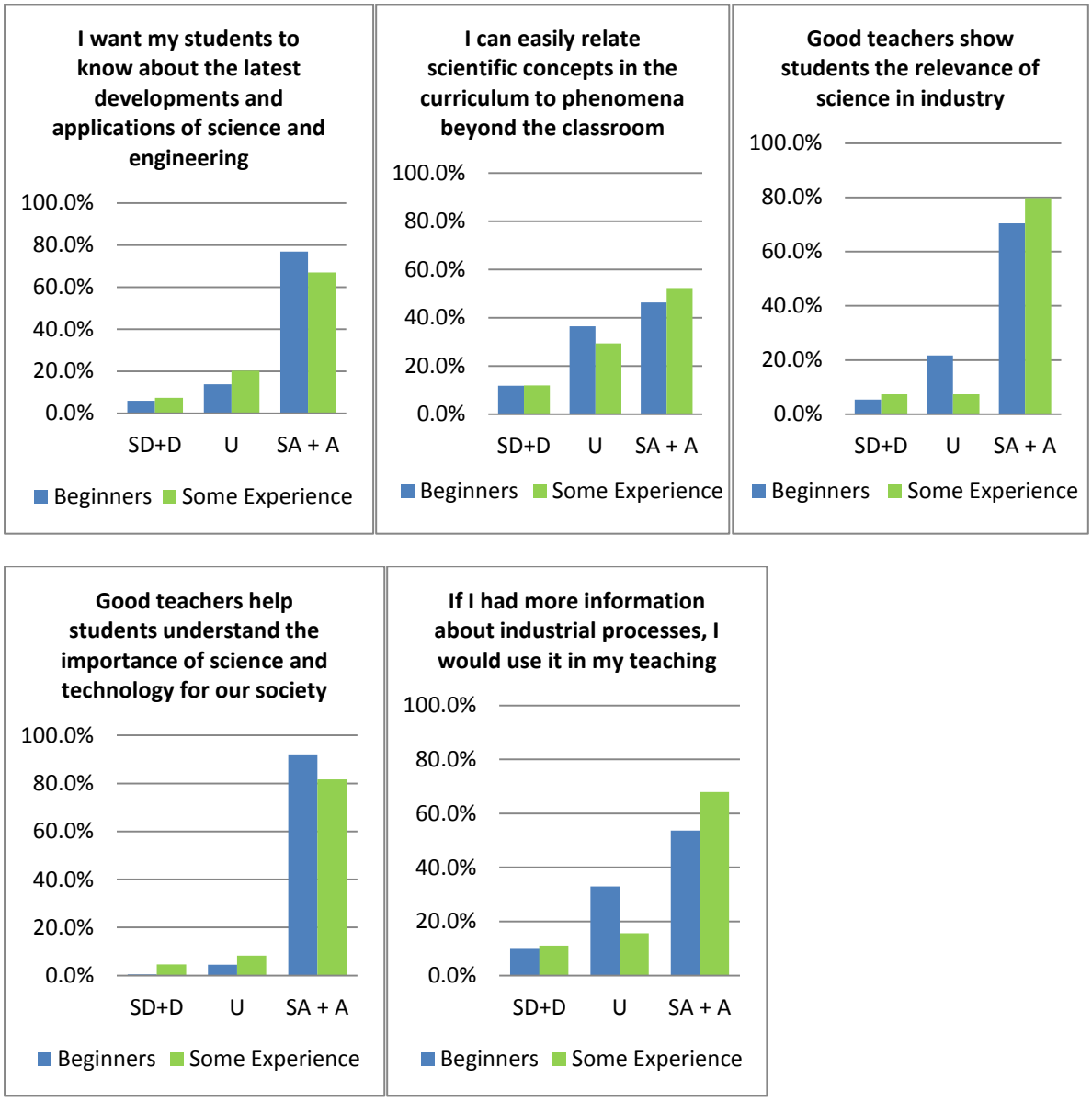

Figure 7: Responses to questions relating to Industrial Links, based on individual teacher experience in IBSE (SD, D, U, A, SA = strongly disagree and disagree, uncertain, strongly agree and agree) Balance to 100% relates to percentage of non-respondents

1.2.4 Practice in the inquiry classroom

Core activities in the inquiry classroom involve student investigations. Teachers can enhance student investigations through questioning, encouraging and probing students' thinking. In terms of determining if these practices occurred at all in the classroom, three statements were posed to the teachers asking the level of agreement to specifically:

- If a student investigation leads to an unexpected result I always tell the students the right answer/result;
- I am unsure how to ask students higher order questions that promotes thinking;
- I have sufficient knowledge of science to implement an inquiry lesson effectively.

If an 'ideal' teacher is encouraging an inquiry classroom, then the 'ideal' response would be strong agreement with first and third statement and strong disagreement with the second. From MDS analysis, there are no cohorts who are close to the ideal (see Figure 8). However, there are differences between the clusters with respect to how they answered the three statements. Overall, the participants in cluster 2 (B, D, H, J and K) were more uncertain about the statement 'If a student investigation leads to an unexpected result I always tell the students the right answer/result' than cluster 1 (C and A). Cluster 1 was also closer to the ideal for 'I am unsure how to ask students higher order questions that promotes thinking'. Cohort E was more uncertain about the statement 'I am unsure how to ask students higher order questions that promotes thinking' and disagreed more with the statement 'I have sufficient knowledge of science to implement an inquiry lesson effectively' than the other cohorts.

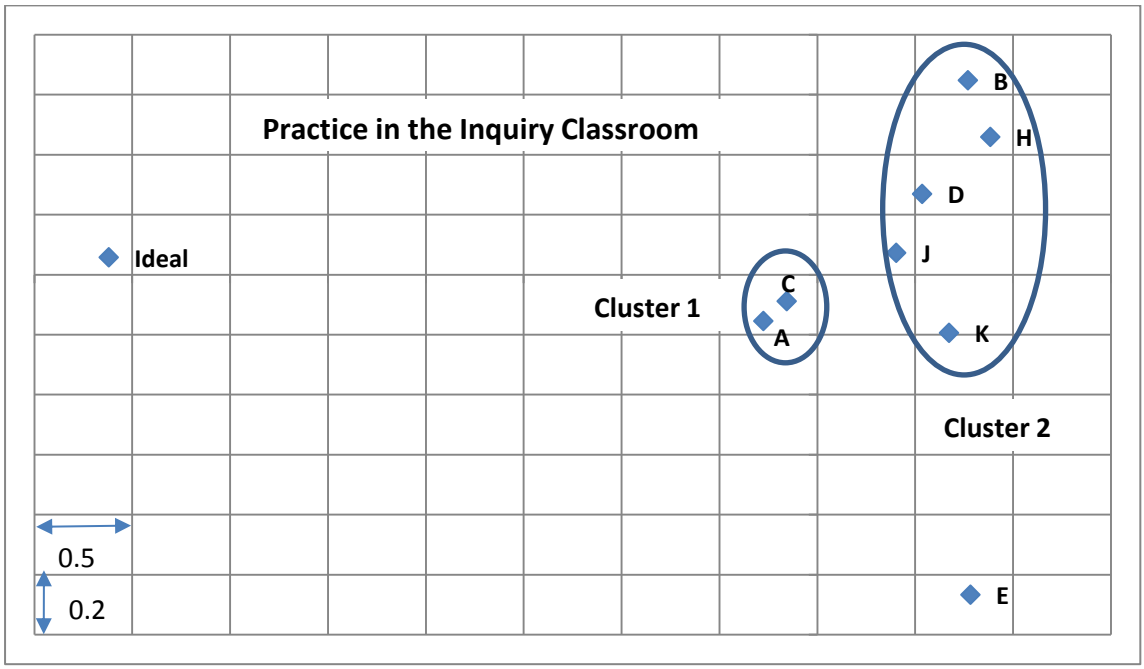

Figure 8: MDS diagram for Practice in the inquiry classroom, based on initial profile

Examining the responses on the basis of teacher experience level, there are some differences evident with SE teachers more likely to not 'tell the students the right answer/result' in an investigation. (Figure 9 and Table A1.4 in Appendix) and the SE teachers also agree more strongly that they have 'sufficient knowledge of science to implement an inquiry lesson effectively'. There is a larger group of BE teachers who disagreed or were uncertain that they had sufficient knowledge of science to implement an inquiry lesson effectively. This cohort is however pre-service teachers and therefore it is expected that this knowledge would be increased as they progress through their own education.

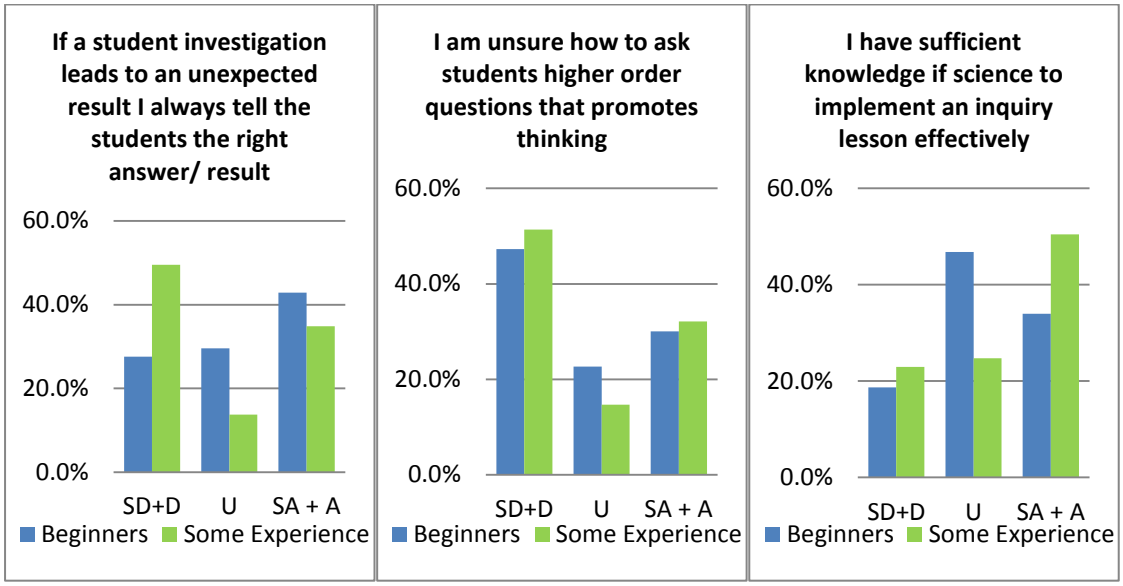

Figure 9: Responses to questions relating to Practice in the Inquiry Classroom, based on individual teacher experience in IBSE (SD, D, U, SA + A =strongly disagree, disagree, uncertain, strongly agree and agree) Balance to 100% relates to percentage of non-respondents

1.2.5 Personal skills in relation to inquiry

Many barriers to the implementation of inquiry have been reported and discussed in D4.1. The teachers' responses to a number of these personal barriers are determined in this section, such as:

- I find it difficult to manage a classroom where each student group is doing different activities;
- I am uncomfortable with teaching areas of science that I have limited knowledge of;
- If I don't know the answers to students questions I feel inadequate as a teacher;
- I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself.

As these questions relate to teachers' self-efficacy, there is really no 'ideal' response – however, for the purposes of the MDS analysis, the ideal was considered to be strong disagreement to all of the above questions. From the MDS, there is a spread of responses from the teacher cohorts, forming two cluster areas (Figure 10).

The differences in location of cluster 2 from cluster 1 can be explained by cluster 1 agreeing more with the statements 'I am uncomfortable with teaching areas of science that I have limited knowledge of' and 'I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself' than cluster 2.

Analysis based on the experience level, indicates that the only difference between the groups is that the BE group is more likely to agree with the statement 'If I don't know the answers to students questions I feel inadequate as a teacher' than the SE teachers. (Figure 11 and Table A1.5).

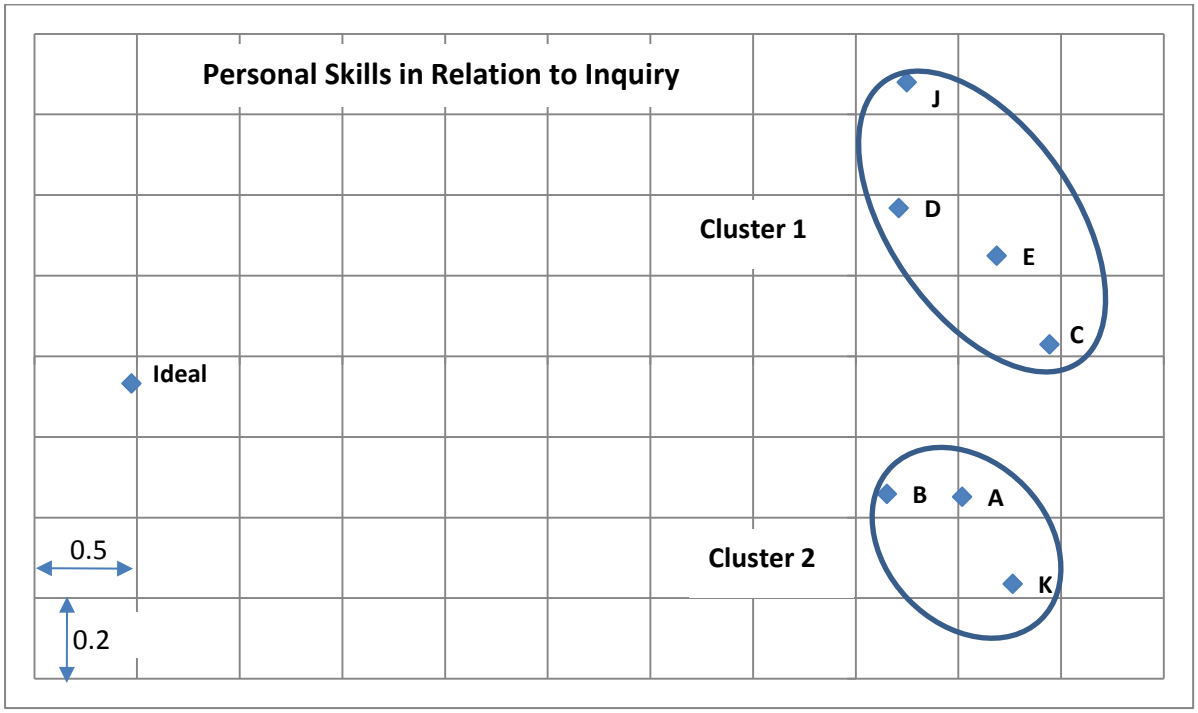

Figure 10: MDS diagram for Personal Skills in relation to inquiry, based on initial profile

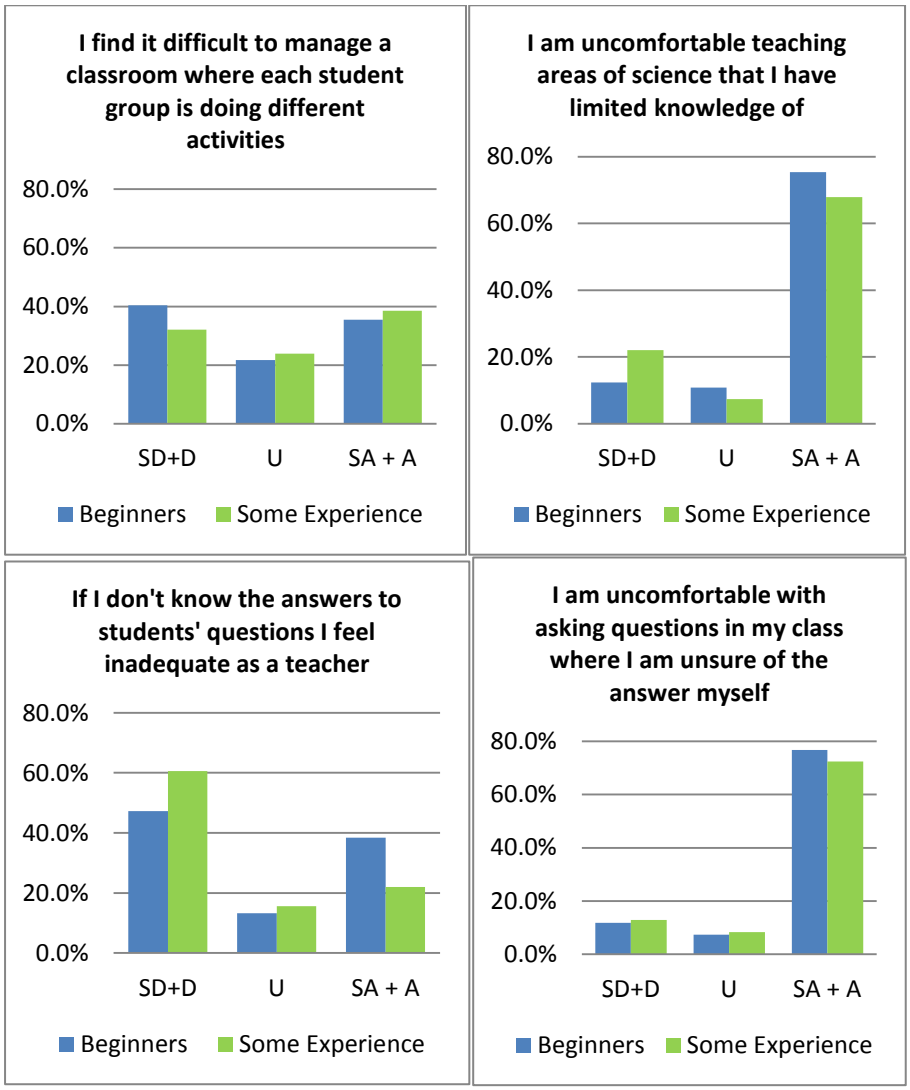

Figure 11: Responses to questions relating to Personal Skills in the Inquiry Classroom, based on individual teacher experience in IBSE (SD, D, U, SA + A = strongly disagree, disagree, uncertain, strongly agree and agree) Balance to 100% relates to percentage of non-respondents

1.3 Conclusion

Approximately three quarters of the pre-service teachers who completed the questionnaires were aged less than 25 years and had less than 20 weeks teaching experience. They rated themselves with regards to their experience with inquiry based teaching, with about a third of the group rating themselves as some experience. All of the cohorts from 8 different countries had a mixture of those beginners with inquiry and some with some experience. The majority (80%) of both the BE and SE groups had 0-20 weeks teaching experience.

Cohort A are an interesting group , even though they are the youngest grouping overall, 61% of them claimed to have some experience with inquiry. Cohort E also had a greater percentage of Some Experience teachers. The type of experience that these pre-service teachers have had with inquiry is not clear as they may have experienced inquiry teaching as a student or they may have actually implemented inquiry practices when they taught.

From MDS analysis, with regard to their understanding of inquiry, cohorts with more BE teachers are found to be farther from the Ideal position than those cohorts where over 60% of their teachers consider themselves as being SE. When considering Attitudes to Inquiry, over 50% of both BE and SE teachers disagree that inquiry based teaching is only suitable for very capable students. This is very positive as inquiry is considered suitable for all students.

The majority of teachers are quite positive towards the Industrial Links, with over 80% of teachers (both BE and SE) agreeing that good teachers help students understand the importance of science and technology for our society. Also over half of the SE teachers feel that they have sufficient knowledge of science to implement an inquiry lesson effectively, compared to just 34% of BE teachers. BE teachers are more likely to agree (38.4%) with the statement “If I don’t know the answers to students questions I feel inadequate as a teacher” than SE teachers (22%). As these are pre-service teachers, they are building scientific knowledge and confidence during their teacher education programme. The variation could be due to the level of progress through their programme.

SECTION 2 Change in profile after Teacher Education Programme

In this section, the change in the teacher profile after teachers attended inquiry programmes are discussed. Note, in some instances the MDS graph already shown in Section 1 differs from that in Section 2 as the data noted in this section is based on individual matched pairs only, i.e. only teachers who had completed both questionnaires are included in the analysis. Also some countries carried out alternative post workshop evaluations, which are reported elsewhere. The proportion of teachers in each country is noted in Table 1. The change in profile, as determined from MDS analysis, is shown under each attribute heading per cohort. The component questions are then considered for each attribute and any differences between the cohorts are highlighted. Finally, the changes based on experience level of the teachers are discussed. Detailed tables of data are referred to under each heading but are included in Appendix 2.

The MDS data analysis shows the change in the average response for each cohort from the initial questionnaire, to the final questionnaire, completed after the TEP. The notation used in the MDS plots is that the asterisk shows the response after the teacher education programme. In all cases, the 'ideal' is defined as in Section 1.

2.1 Understanding of inquiry

Overview

Teachers' overall understanding of inquiry is determined from their responses to questions asking them to rate their understanding of IBSE, as well as their understanding of their role as a teacher and the role of the students in the inquiry classroom. The MDS plot for each cohort at the beginning and after the TEP is shown in Figure 12.

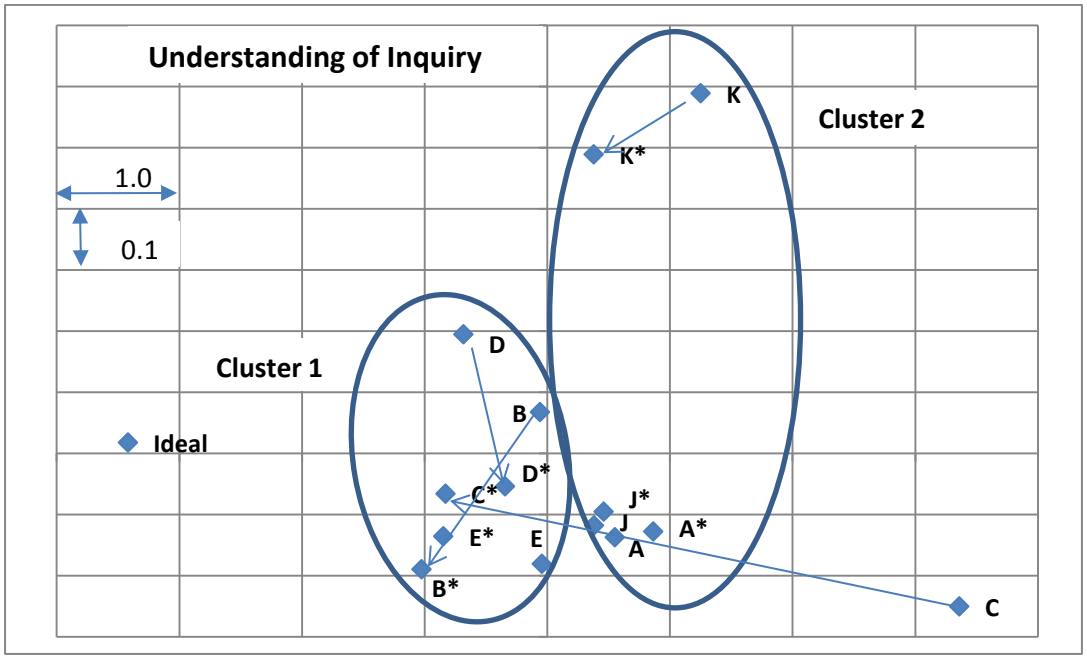

Figure 12: MDS of Understanding of Inquiry, based on matched pairs, per cohort (* denotes responses after teacher education programme)

Two distinct clusters can be seen in the MDS; Cluster 1 (B, B*, C*, D, D*, E and E*) show responses that are closer to the ideal than those given by cluster 2 (A, A*, J, J*, K and K*). One cohort (C) is furthest from the

cluster as they indicate that they are uncertain about whether they understand inquiry, the role of the teacher, and the role of the student in the inquiry classroom. Cohorts B, C, E and K shifted towards the ideal responses after the TEP with cohort C making the greatest shift. The remaining cohorts either stayed the same or shifted only slightly.

Component Questions

From averaged responses to each of the individual questions, there are statistically significant changes to the mean (based on Wilcoxon Signed Rank Test) for many cohorts, showing that teachers understanding has increased (shifted towards the ideal) (see Table A2.1 in Appendix 2 for details). Specifically,

- increased understanding of IBSE - by cohort C;
- increased understanding of role of teacher in the inquiry classroom - by cohorts B, C;
- increased understanding of role of student in the inquiry classroom - by cohorts B, C;

So there is clear indication that workshops have increased participants understanding of inquiry and the role of the teacher and of the student in the inquiry classroom, particularly by these cohorts.

Teacher Experience Level

Statistical differences are evident in the changes of the mean scores of the BE cohort and SE cohort of teachers (Table A2.1 in Appendix 2). As the teacher groups in most cohorts have different combinations of teachers who are BE , SE and VE in inquiry, the MDS was carried out on the BE cohort and the SE cohort (there were few VE teachers so this group was not included). Selecting all the BE group from across all the cohorts gives 149 teachers. The MDS plot of their profile before and after TEP is shown in Figure 13. This graph is difficult to interpret as there are many individuals 'hidden' within each data point, as they have given the same responses on the questionnaire. From the arrangement of the data points, it is clear that there is less variation in the 'after TEP' data. Therefore, the change that has occurred was examined in the following way.

As the responses to the questionnaires were categorical (i.e. responses 1-5), each point on the MDS denotes a particular combination of answers. As shown in Figure 14, clusters could be made where the numerical sum of the scores was increasing with distance from the ideal. Therefore 5 clusters were identified according to the sum of the responses to the three questions as follows: 'Strongly Agree with ideal' (absolute difference from ideal position less than or equal to 1, e.g. coded responses such as (1,1,1), (1,2,1) or (2,1,1)); 'Agree with ideal' (absolute difference from ideal position between 2 and 3, e.g. coded responses such as (2,2,1);(3,1,1); (2,2,2)); 'uncertain' (absolute difference from ideal position between 4 and 6); 'disagreeing with ideal' (absolute difference from ideal position between 7 and 9); and 'strong disagreement with ideal' (absolute difference from ideal position greater than 10). Figure 14 shows the number of teachers within each category in both the initial and final surveys for both the BE and SE groups. Clearly, there is a shift towards the ideal by the BE group of teachers; however there is little change in the SE group.

Key conclusion

The programme has resulted in increased understanding of inquiry and the role of teacher and student in the inquiry classroom, particularly by those who are BE; there is little change in the SE cohort.

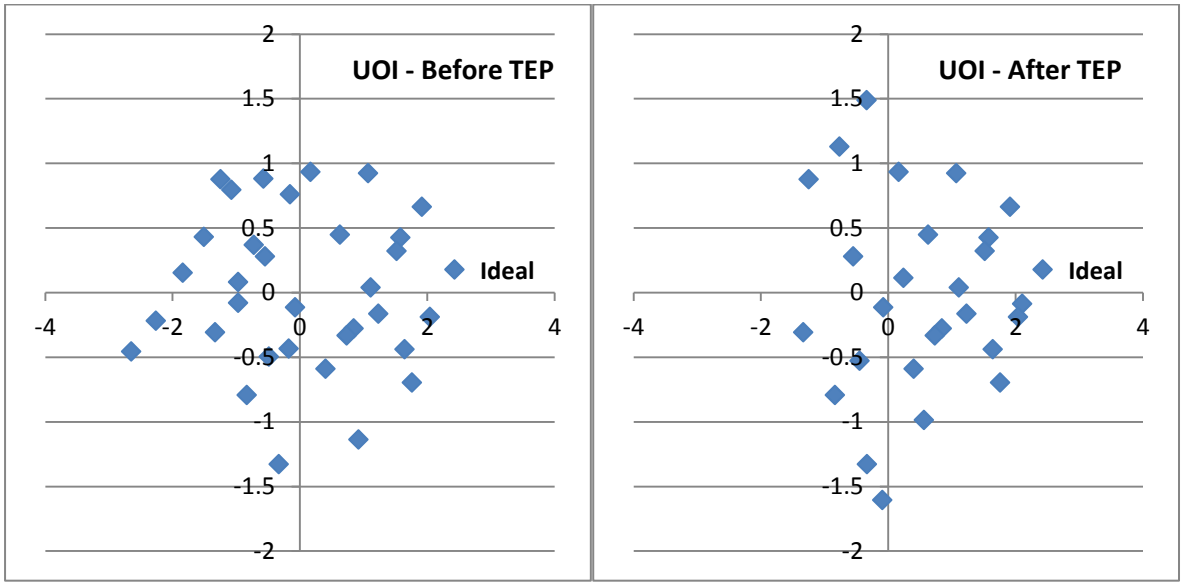

Figure 13: MDS of BE group Understanding of Inquiry, before and after the TEP

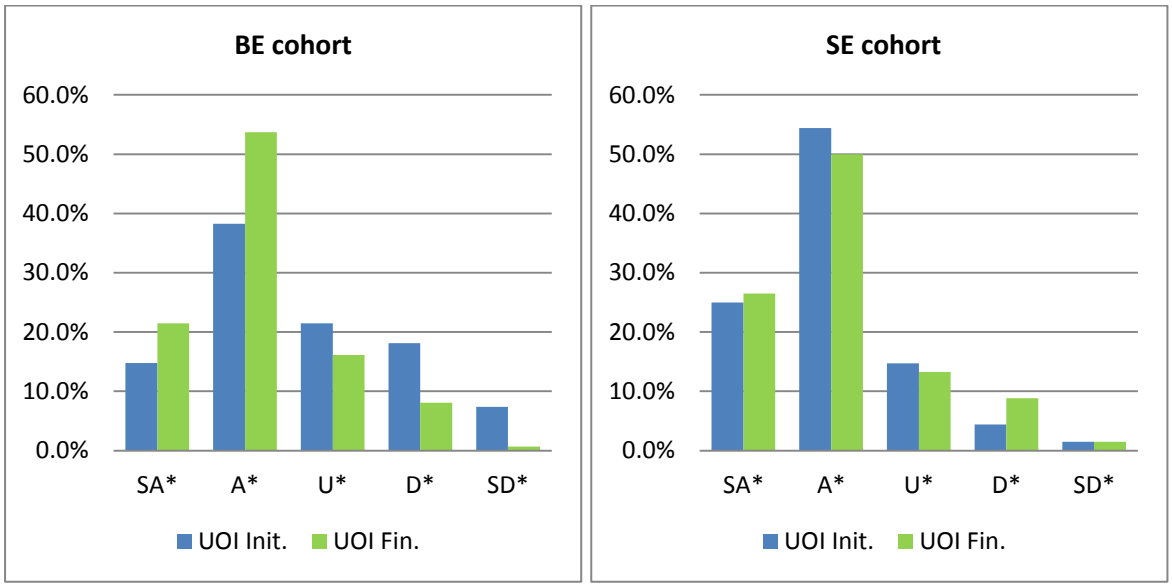

Figure 14: Proportion of teachers within cluster groups initially and finally (a) BE cohort, (b) SE cohort (UOI Init = Understanding of Inquiry from initial questionnaire, UOI Fin = Understanding of Inquiry from final questionnaire) (SA*, A*, U*, D*, SD* = strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

2.2 Attitude to inquiry

Overview

Responses on attitudes to inquiry by matched pairs of teachers were analysed by MDS and plotted in Figure 15. The questions used are as already given in Section 1.2.2. Two clusters are evident on the MDS plot. The change in responses by each cohort after the teacher education programme is shown in Figure 15, showing a shift towards the ideal by cohorts A and C. Generally, cluster 2 (A, A*, C, E and E*) are more uncertain towards all three statements than cluster 1 (B, B*, C*, D, D*, J, J*, K and K*), who disagree that 'inquiry takes up too much classroom time for me to implement' and that 'Inquiry based teaching is only suitable for the very capable students'.

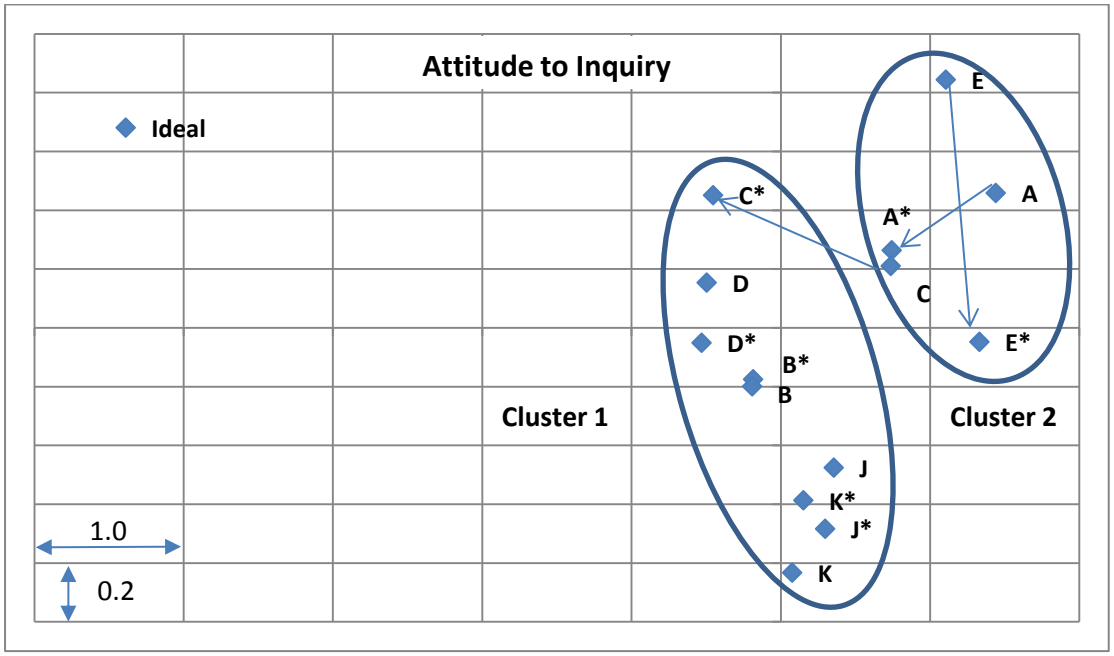

Fig 15: MDS of Attitude to Inquiry, based on matched pairs, per cohort (* denotes responses after teacher education programme)

Component Questions

Statistically significant changes ($p<0.05$) in the mean responses to individual questions before and after the teacher education programme (Table A2.2 in Appendix2), show that the changes evident in particular cohorts are due to changes in the level of agreement to particular statements:

- Inquiry takes up too much classroom time for me to implement - from uncertain to disagree by cohort C;
- Use of inquiry is appropriate to achieving the aims of the curriculum - from uncertain to positive agreement by cohort C;
- Inquiry based teaching is only suitable for the very capable students – move to more strongly disagree by overall cohort and particularly cohort C.

Teacher Experience Level

Significant differences ($p<0.05$) can be seen for the mean responses in this section by the BE cohort (see Table A2.2 in Appendix 2). As detailed under Section 2.1, the responses to the questions for the BE cohort were plotted on MDS plot and categorised with regard to distance from ideal. Five categories were identified (Fig A2.1) and the number of teachers within each category was compared, before and after the TEP. The numbers of teachers in each of the categories is shown in Fig 16, for both the BE cohort and the SE cohort. The BE group has moved more towards the ideal than the SE group, and after the TEP, half of the group are closer to the ideal while the SE group are more uncertain.

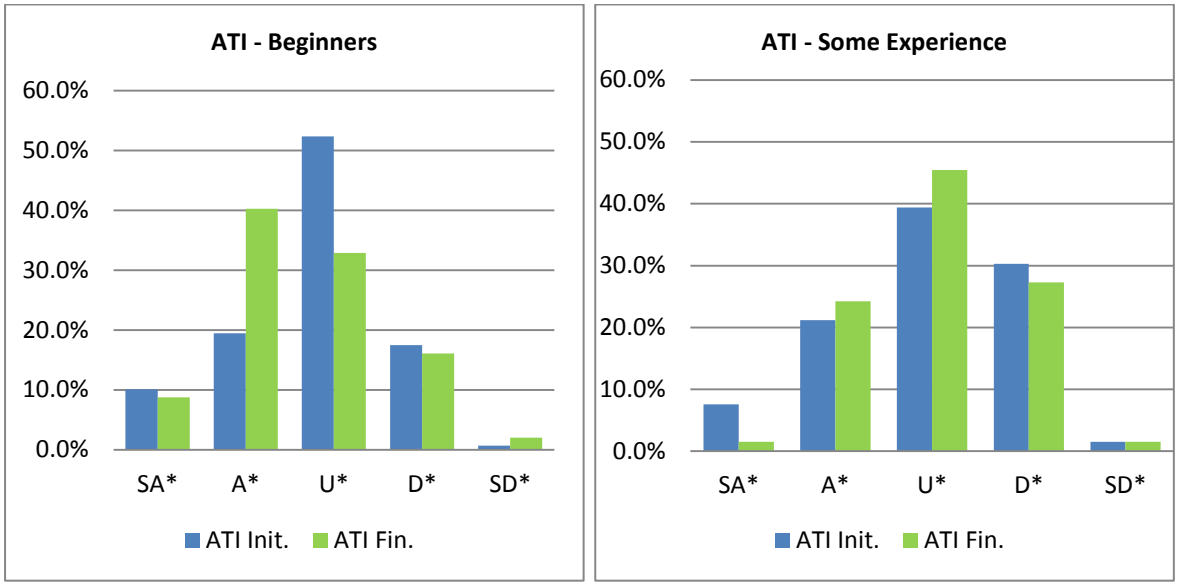

Fig 16: Numbers of teachers in each category, before and after the teacher education programme for BE and SE cohorts (ATI, attitude to Inquiry; Init, Fin are Initial and final questionnaires) (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

Key conclusion

From this data, it is clear that the attitudes to inquiry have shifted towards the ideal response by some of the teacher cohorts and particularly, the shift seems to be more significant on the BE group. The SE group seem to be more uncertain in their attitudes and these do not shift over the TEP.

2.3 Industrial Links

Overview

MDS analysis of responses to questions relating to industrial links is shown in Figure 17. Two clusters are evident. Cluster 1 (B*, E, E*, J* and K*) are more uncertain about all of the statements than cluster 2 (cohorts A, A*, B, C, C*, D, D*, J and K). Only cohort D shifted more towards the ideal response after TEP. The shifts shown by other cohorts were generally away from the ideal responses; the individual component questions are discussed below.

Component Questions

Statistically significant changes ($p<0.05$) in the mean responses to individual questions before and after the TEP (Table A2.3 in Appendix2), show that the changes evident in particular cohorts are due to changes in the level of agreement to particular statements:

- I want my students to know about the latest developments and applications of science and engineering – move from 'uncertain' to 'agree' by cohort D; but opposite movement by cohort A from 'agree' to 'uncertain'.
- I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom – whole cohort moved from 'uncertain' to 'agree', particularly cohorts A, B, D and C.
- I often show students the relevance of science in industry – whole cohort increased in 'uncertainty' with cohort A, B and J moved from 'agree' to 'uncertain'.
- My students understand the importance of science and technology for our society – whole cohort shifted from 'agree' to 'uncertain', particularly cohorts A, B, C, D and J.

- If I had more information about industrial processes, I would use it in my teaching – cohort D moved from 'uncertain' to 'agree'.

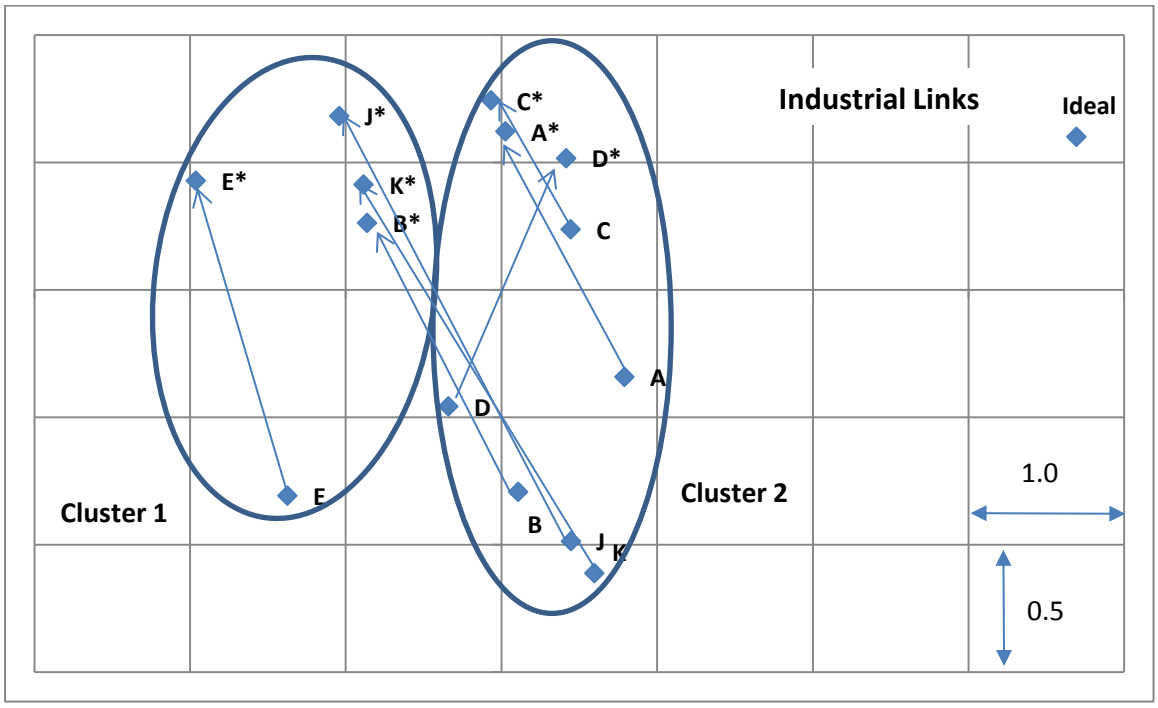

Fig 17: MDS diagram for Change in Industrial Links as shown by matched pairs, per cohort (* denotes responses after teacher education programme)

Teacher Experience Level

Significant differences ($p<0.05$) can be seen for the mean responses in this section by the BE cohort compared to the SE group (see Table A2.3 in Appendix 2). As detailed under section 2.1, the responses to the questions for the BE or SE cohorts were plotted on MDS plot and categorised with regard to distance from ideal. Five categories were identified (Figure A2.3) and the number of teachers within each category was compared, before and after TEP. The numbers of teachers in each of the categories both before and after the teacher education programme is shown in Figure 18, for both the BE cohort and the SE cohort. The movement away from the ideal responses is clear for both BE and particularly the SE cohort.

Key conclusion

Examining the change in the BE and SE cohorts, there is movement away from the ideal responses by both cohorts. Within the BE cohort, the majority of the participants are in the 'uncertain*' or 'disagree with ideal*' category. In the SE cohort, over 10% moved from being 'uncertain*' to 'disagree with ideal*' category.

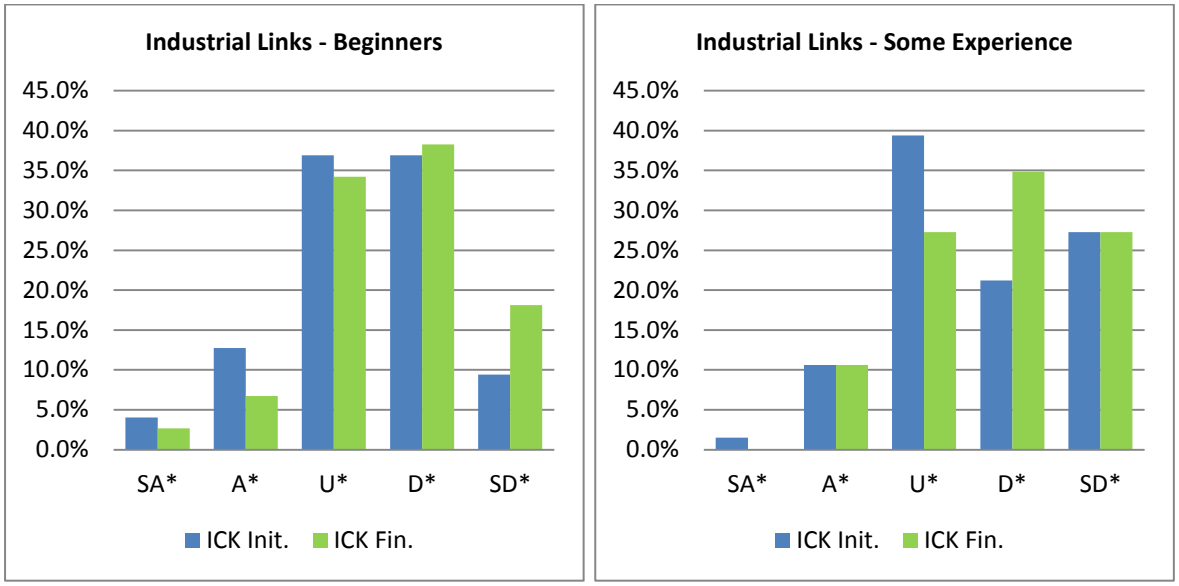

Figure 18: Numbers of teachers in each category, before and after TEP for BE and SE cohorts (Industrial Links) (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

2.4 Practice in the inquiry classroom

Overview

Changes in relation to practice in the classroom, analysed by MDS analysis, are shown in Figure 19. Two clusters are evident, with Cluster 1 (A, A*, B*, C, C* and K*) closer to the ideal, mainly due to a more ideal response on two statements, "If a student investigation leads to an unexpected result I always tell the students the right answer/result" and "I am unsure how to ask students higher order questions that promotes thinking", than Cluster 2 (B, D, D*, E, E*, J, J* and K). Cohorts E, C and K moved towards the ideal after the TEP, while the other cohorts did not move to any extent (Figure 19).

Component Questions

Statistically significant changes ($p<0.05$) in the mean responses to individual questions before and after the teacher education programme (Table A2.4 in Appendix2), show that the changes evident in particular cohorts are due to changes in the level of agreement to particular statements. Each statement significant change is considered below, noting that some cohorts moved towards the ideal response while others moved away:

- If a student investigation leads to an unexpected result I always tell the students the right answer/result – Cohort A moved from 'disagree' towards 'uncertain';
- I am unsure how to ask students higher order questions that promotes thinking – Cohort B moved to agreement;
- I have sufficient knowledge of science to implement an inquiry lesson effectively – whole cohort moved significantly away from the ideal; however, Cohorts C and E moved from 'disagree' to 'uncertain' and B moved towards ideal, but were still 'uncertain'.

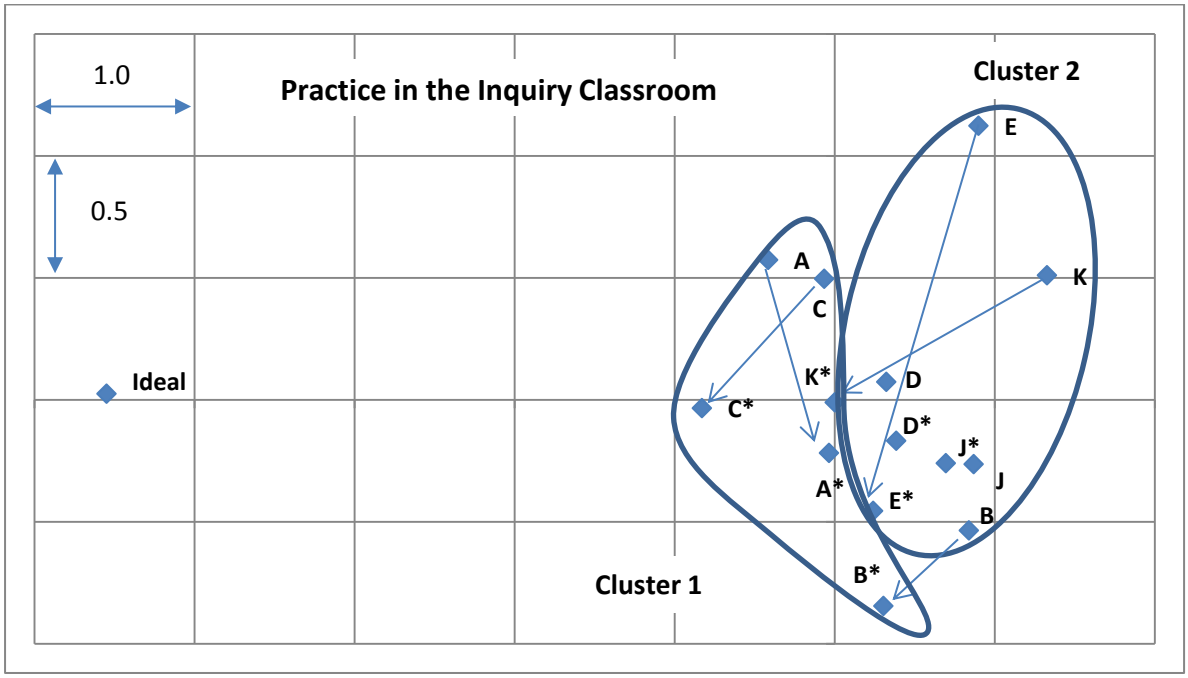

Figure 19: MDS diagram for Change in Practice in the Inquiry Classroom as shown by matched pairs, per cohort (* denotes responses after teacher education programme)

Teacher Experience Level

Separating responses to the statements based on experience level, the BE cohort has shifted towards a stronger disagreement with the ideal (Figure 20) while the SE cohort seems to have moved in the opposite direction. The change in the SE cohort seems to be mainly due to a more ideal response to "I have sufficient knowledge of science to implement an inquiry lesson effectively" and "I am unsure how to ask students higher order questions that promotes thinking".

Key Conclusion

The bigger effect here seems to be with the SE cohort, who is more confident of asking higher order questions and of having sufficient science to enable an inquiry classroom. This may imply that pre-service teachers need to have some experience with inquiry practices in the classroom before they can then build on their basic practice.

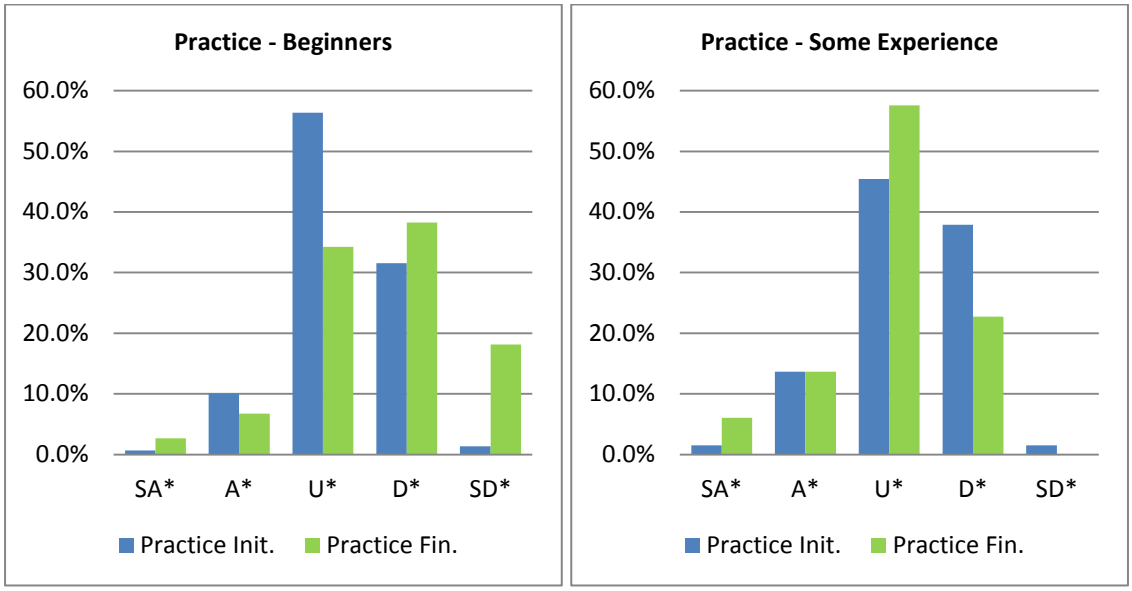

Figure 20: Numbers of teachers in each category, before and after the TEP for BE and SE cohorts (Practice) (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

2.5 Personal skills in relation to inquiry

Overview

Changes in the personal attributes of teacher cohorts were determined from the questionnaire and MDS plot is shown in Figure 21. Two clusters are evident, but both equidistant from the ideal response. Cluster 1 (C*, J, J*, K and K*) disagree more with the statements "I find it difficult to manage a classroom where each student group is doing different activities", "If I don't know the answers to students questions I feel inadequate as a teacher" and "I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself" than cluster 2 (A, A*, B, B*, C, D, D*, E and E*). Overall, the cohorts in both clusters are uncertain to the statement "I am uncomfortable with teaching areas of science that I have limited knowledge of".

There was relatively little movement in the MDS plot after the TEP, with small changes evident in individual questions.

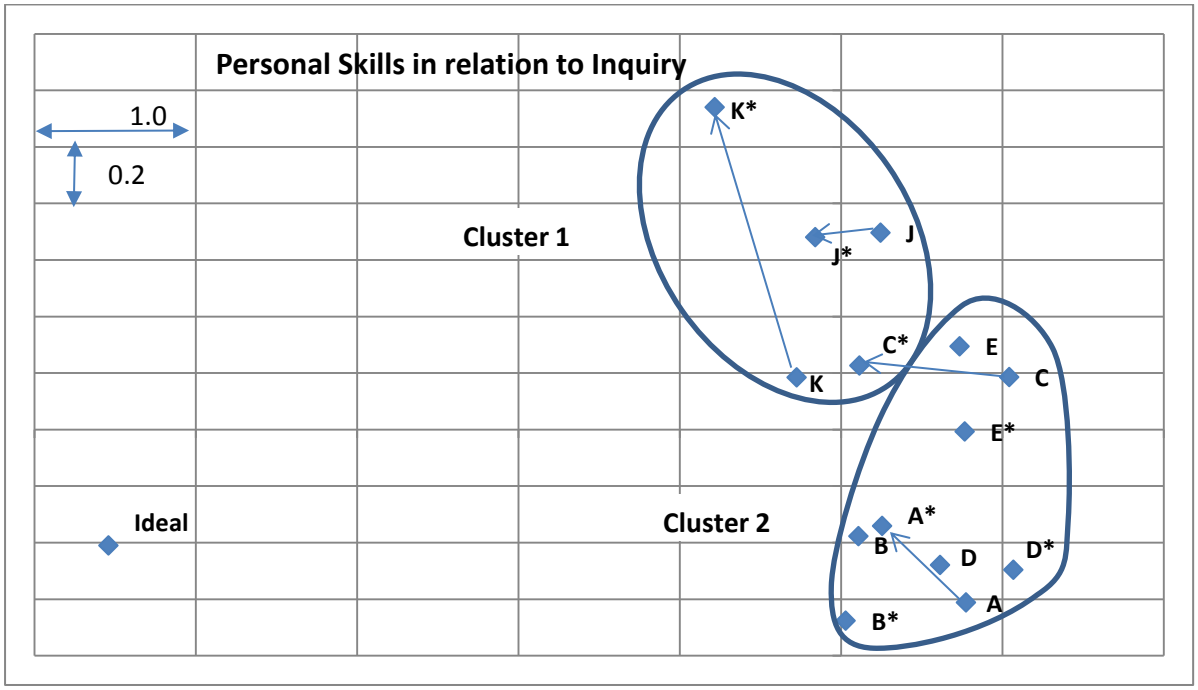

Figure 21: MDS diagram for Change in Personal skills as shown by matched pairs as shown, per cohort (* denotes responses after teacher education programme)

Component Questions

Statistically significant changes ($p<0.05$) in the mean responses to individual questions before and after the TEP (Table A2.5 in Appendix2), show that the changes evident in particular cohorts are due to changes in the level of agreement to particular statements. However, in some instances the shifts were not towards the ideal, and rather, away from it.

- I find it difficult to manage a classroom where each student group is doing different activities – No significant changes in any cohort;
- I am uncomfortable with teaching areas of science that I have limited knowledge of – Cohort C shifted from 'agree' to 'uncertain';
- If I don't know the answers to students questions I feel inadequate as a teacher – Cohort A shifted from 'uncertain' to 'disagree';
- I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself – Cohort C moved from 'agree' to 'uncertain', while cohort D moved from 'uncertain' to 'agree'.

Teacher Experience Level

From Figure 22, it is clear that based on experience level, there is only a small shift for the BE cohort while the SE cohort do not show any change.

Key conclusion

From these graphs, it is evident that there is very small movement of both the BE and SE groups towards ideal. However, there still seems to be a lot of work necessary in this area to improve and enhance teachers' confidence. As these teachers are pre-service, this result is expected as the teachers are preparing for this career.

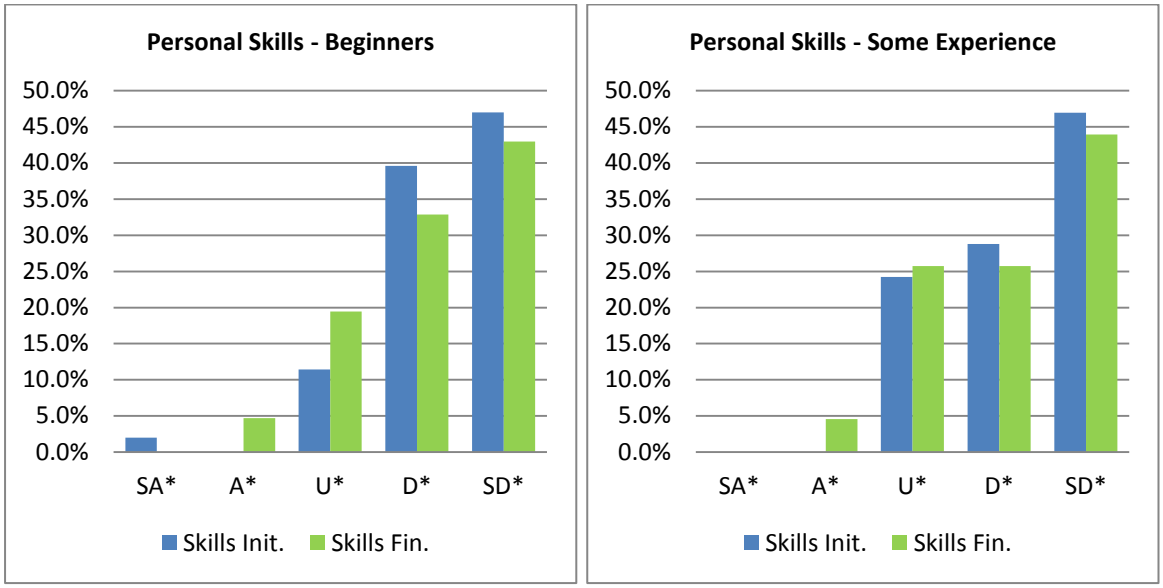

Figure 22: Numbers of teachers in each category, before and after the teacher education programme for BE and SE cohorts (Personal Skills) (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

SECTION 3 Gender Effects

3.1 Overview

The overall cohorts of teachers who attended and completed the questionnaires were 367 for the initial questionnaire and 249 post questionnaires. Of the initial cohort, 35% were male and 66% were female. From the matched pairs (i.e. completed both questionnaires), 29% of the participants were male, and 71% were female.

As discussed in Section 1 and Section 2 above, many of the differences that have been noted in the main attributes have been explained by differences in the experience level of the teachers with inquiry. This is also true for differences in individual questions. Therefore, analyzing the data based on gender only will lead to mis-interpretation of the data and therefore it is not appropriate to look at differences in mean responses to particular questions or groups of questions based on gender only.

To determine if there are differences in responses by males and females, the group was subdivided into 4 groups: BE male, BE female, SE male and SE female (Table 3.1). Due to the small number in the VE group, they have been included in the SE group for analysis. The MDS analysis was then carried out on each cohort and the shift from before to after the TEP was determined (as explained in Section 2) and shown in Figure 23 for BE group and Figure 24 for SE group.

Table 3.1: Number of matched pair responses for Gender groups based on experience level

	Total	B	SE	VE
Male	62	40	22	0
Female	155	109	45	1

3.2 Beginner Cohort (BE)

The change in matched pair responses for the BE group, based on gender, for each attribute is given in Figure 23. All of the following results must be interpreted with care as the differences may be due to responses to individual questions and small differences may be exaggerated due to small numbers. With that proviso, then general trends may be noted.

From Figure 23 (a), both the male and female groups have shown an increase in their understanding of inquiry, and the roles of the teacher and student in the inquiry classroom, after the TEP, with approximately similar proportions of males and females who have shifted to strongly agree/agree with the ideal response.

Similarly with regard to Attitudes to inquiry (Figure 23(b)), there is a significant movement of both males and females to agreeing/strongly agreeing with the ideal, after the TEP (17 to 40 % for males, 34 to 52% for females). However, there are also a number of males (7.5%) who have moved to strongly disagreeing with the ideal after the TEP. There are no reasons evident for this movement.

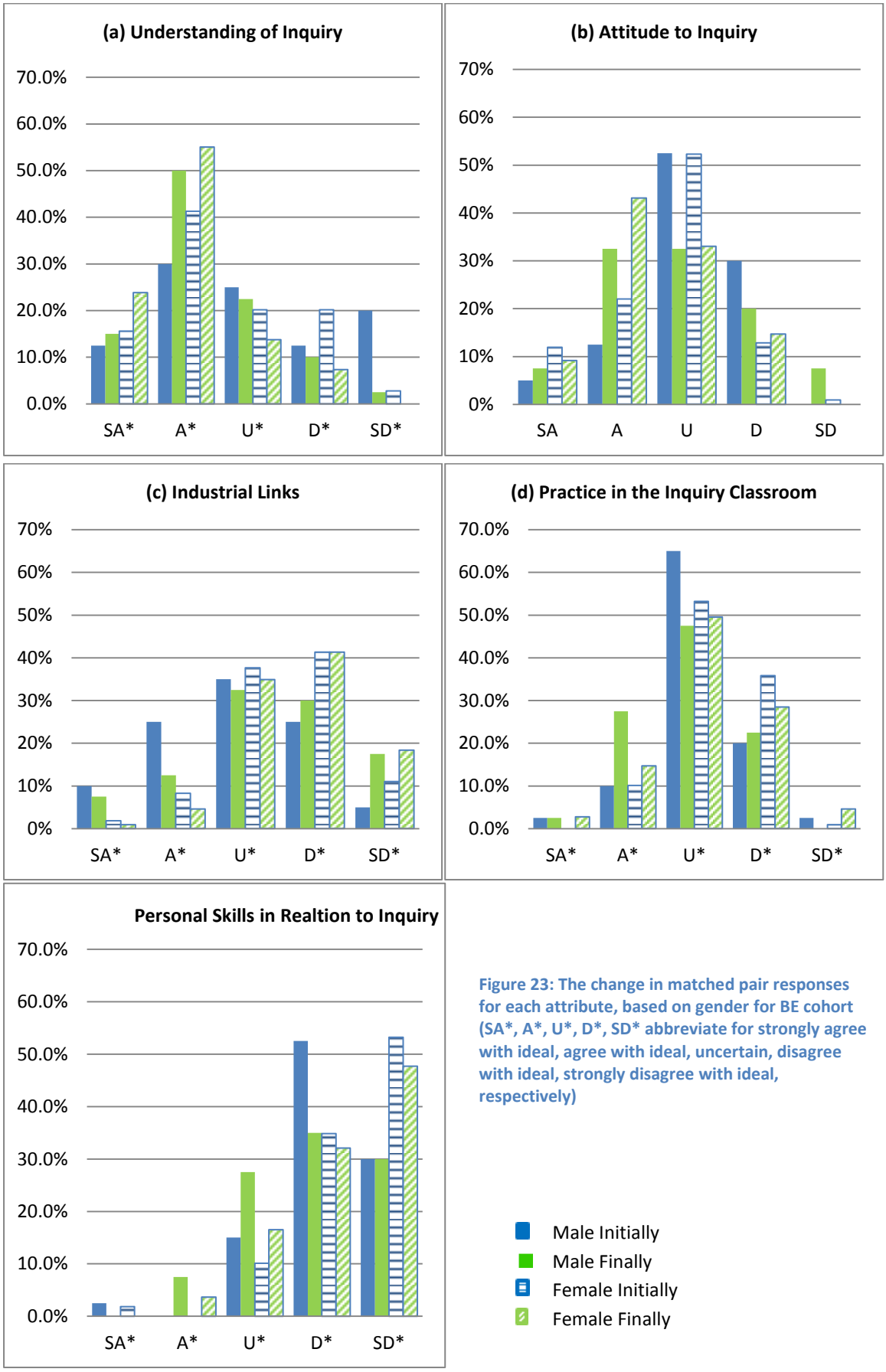

Figure 23: The change in matched pair responses for each attribute, based on gender for BE cohort (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

In terms of developing industrial links, there seems to be a difference between male and female respondents (Figure 23(c)). Initially the male cohort divide roughly into thirds, with one-third strongly agreeing/agreeing

with the ideal, one third uncertain and on-third disagreeing/strongly disagreeing with the ideal. After the TEP, this shifts to 20% strongly agreeing/agreeing with the ideal and almost half disagreeing/strongly disagreeing with the ideal. The female cohort has shifted slightly towards disagreement but the effect here is very small.

The modal response to the practice in the classroom (Figure 23(d)) for both male and females is 'uncertain' both initially and after the TEP. However, the male cohort have shifted more towards 'agree with ideal' after the TEP, due mainly to a more positive response to the statement "I have sufficient knowledge of science to implement an inquiry lesson effectively" that the females, who were largely 'uncertain' to this statement.

With regard to development of personal skills in relation to inquiry, it is clear that the participants are pre-service teachers who are developing their confidence in teaching. Over 80% of males and nearly 90% of females 'disagree / strongly disagree with ideal' initially and this reduces to 65% for males and 82% for females. The male group have shifted towards being 'uncertain'. This difference may be partially explained by the significant difference in responses after the TEP to the statement "I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself", with the females more in agreement than the male cohort.

3.3 Some Experience Cohort

The change in matched pair responses for the SE group, based on gender, for each attribute is given in Figure 24. All of the following results must be interpreted with care as the differences may be due to responses to individual questions and small differences may be exaggerated due to small numbers. With that proviso, then general trends may be noted.

From Figure 24 (a), both the male group has shown an increase in their understanding of inquiry, and the roles of the teacher and student in the inquiry classroom, after the TEP, with no real shift by the female cohort. This may be due to the fact that most of the female group were already 'strongly agreeing/agreeing with the ideal' before the TEP.

In terms of attitudes to inquiry (Figure 24(b)), there is a shift in male respondents from 'disagree with ideal' to 'agree with ideal' after the TEP. The female group, however, shift slightly in the opposite direction to 'disagree with ideal' after the TEP. This may be due to the responses to the statement 'Inquiry based teaching is only for very capable students' where there were significant differences between the responses of the males who disagreed with the statement, while the females strongly disagreed.

The modal response to statements relating to industrial links (Figure 24(c)), remains as 'uncertain' for the male cohort initially and after the TEP, while the female cohort shifts from 'uncertain' to 'disagree with the ideal'. This was due to significantly different responses by the male and female cohorts to the statements: 'I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom', I often show students the relevance of science in industry' and 'If I had more information about industrial processes, I would use it in my teaching', with the male cohort responding closer to the ideal response than the female cohorts. Further analysis of student background would be necessary to investigate these responses.

In terms of practice in the classroom, the male cohort has shown very little change after the TEP; however, the female cohort has increased in 'uncertainty' from 'disagreeing with ideal'. Males disagreed with the statement 'I am unsure how to ask students higher order questions that promotes thinking' significantly more strongly than females.

The modal responses for males and females in terms of personal skills in relation to inquiry are 'disagree with ideal' for males group and 'strongly disagree with ideal' for female group. There is little change in either cohort after the TEP. Again it should be noted that these teachers are pre-service and are developing the

skills necessary for teaching and therefore, no change would be expected over a short intervention programme.

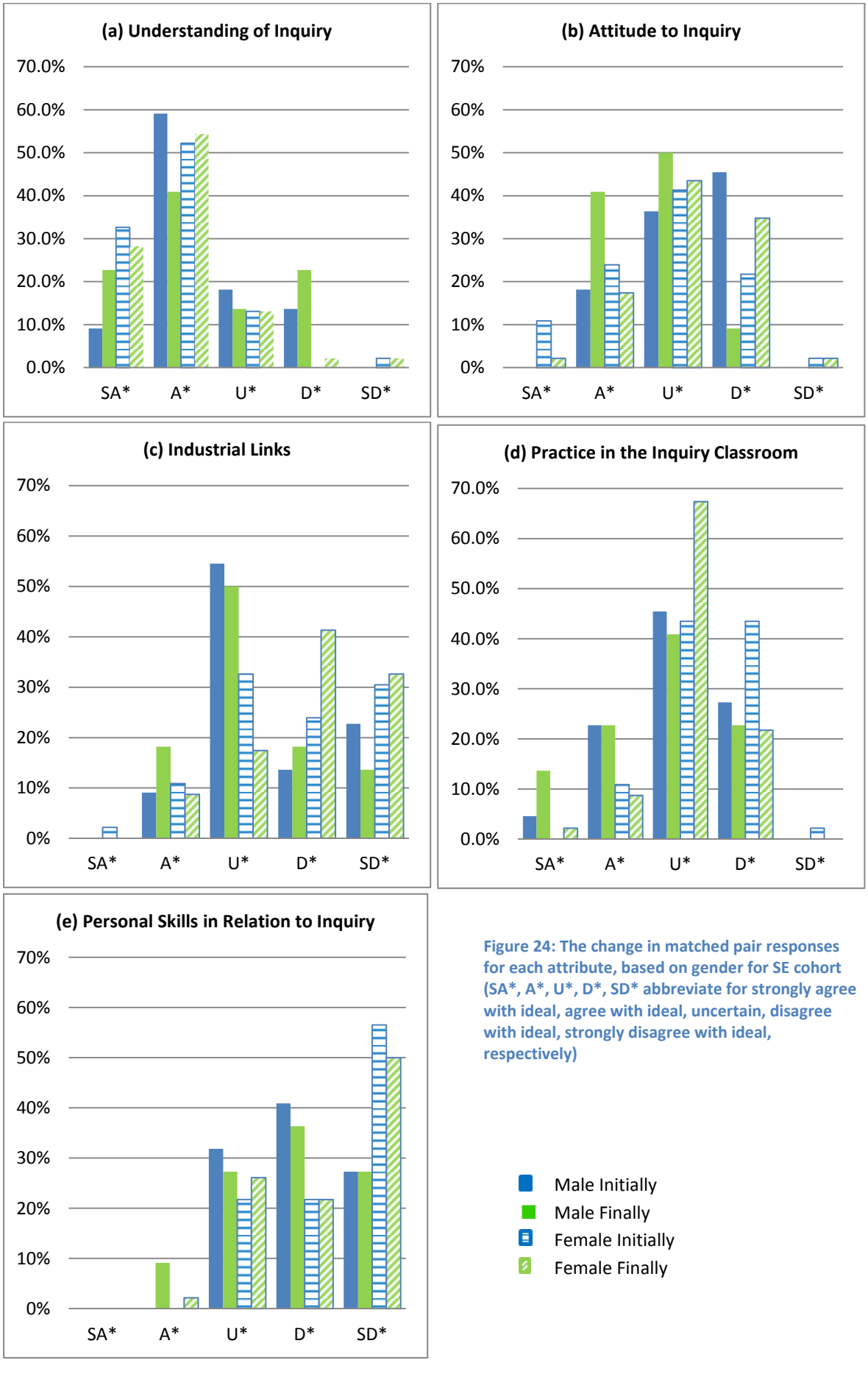

Figure 24: The change in matched pair responses for each attribute, based on gender for SE cohort (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

SECTION 4 Statistical Analysis

Individual teacher responses to questionnaires were recorded by each partner in a specially designed excel workbook which was then forwarded to the authors of this report for collation and analysis. Each Likert-style question has a set of 5 responses, coded from 1 to 5, from 'Strongly Disagree' to 'Strongly agree'.

The individual question items in the ITQ-A were sorted into five categories, as follows, in order to represent the results:

- Understanding of inquiry
- Attitude towards inquiry
- Industrial links
- Practice in the inquiry classroom
- Personal skills in relation to inquiry

Multi-dimensional Scaling (MDS) analysis using an ALSCAL algorithm was used to examine similarity/dissimilarity between data. Ward's method was used to determine the number of clusters in the dataset, followed by a k-means algorithm used to determine which cluster a particular data point belonged to.
In Section 1, MDS was used to compare the dissimilarity between the different country groups by using the country average response for each question as the input for MDS. The distribution of the responses based on each teacher cohort was then mapped relative to an 'ideal' response as described in the preceding sections. In Section 2, this process was repeated, but in this case only teachers who had completed both questionnaires were included in the analysis.

Descriptive statistics (e.g., derivation of mean responses, percent of responses, etc.) were conducted on each dataset obtained from each partner. The data from all countries was then combined into one data set. The Wilcoxon Signed Rank test (non-parametric equivalent of the independent t-test) was used to examine if there was a difference in teachers' responses to the questionnaire between the beginning and end of the training programme. The Mann Whitney test (non-parametric equivalent of the dependent t-test) was used to examine whether there was a gender difference in responses to the questionnaire.

OVERALL CONCLUSIONS

In the teacher education programmes for pre-service teachers, ESTABLISH partners used many of the resources and materials developed within the project and adapted the In-service TEP for use with the pre-service group. The pre-service teachers who attended the ESTABLISH TEP were asked to complete two questionnaires, one at the start of the TEP and the other after the TEP was completed. The data has been analysed to determine the following attributes of the teachers in relation to the initial profile of the teachers and also to determine the change that occurs after completing the TEP:

- Understanding of inquiry
- Attitude towards inquiry
- Industrial importance/links
- Practice in the inquiry classroom
- Personal Skills in relation to inquiry

Approximately 70% of the group were aged less than 25 years and roughly 65% were female. The pre-service teachers rated themselves on the basis of their experience with inquiry based science education as beginners (BE), with some experience (SE) or very experienced (VE). Using this rating, the overall cohort consisted of 59% BE, 33% SE and 1% VE teachers.

Each of the cohorts of teachers followed different programmes as the ESTABLISH material was integrated to varying extents within the various programmes. Given this diversity of teacher training programmes, the pre-service teacher backgrounds and the range of teaching experience, there is a surprising homogeneity across the overall group. This is particularly in terms of their understanding of inquiry and their attitudes to inquiry.

Small changes in pre-service teachers' understanding of inquiry, and the role of teacher and student in the inquiry classroom and attitudes to inquiry are evident after the TEP, particularly for those that are beginners with inquiry. While some of the pre-service teachers have rated themselves as having some experience with inquiry, it is not clear if these pre-service teachers have experienced inquiry teaching as a student or whether they have actually taught through inquiry themselves.

In terms of practice of inquiry skills in the classroom, there is a more positive shift by those with some experience after the TEP than the beginner group; this may suggest that it takes time to develop the skills necessary and those with some experience themselves are more prepared to further develop their skills. The skills necessary to implement inquiry in the classroom are evident in the pre-service teachers with some experience of inquiry, who become more confident of having sufficient science knowledge to enable inquiry in the classroom and of asking higher order questions, over the TEP.

Pre-service teachers need to be aware of the importance of industrial links, as outlined by the ESTABLISH project. Over the course of the TEP, both groups of pre-service teachers shift towards agreeing that they can easily relate science concepts in the curriculum to phenomena beyond the classroom; however, they are still more uncertain about students knowing the relevance and importance of science and technology in industry and in society.

Overall, the pre-service teachers develop their understanding of inquiry and develop their attitudes towards inquiry. While there are some small shifts evident based on gender, these results have to be treated with caution as the main differences between the groups seem to relate to the experience level of the pre-service teachers with respect to inquiry and also to the particular cohort that they are part of, i.e. their previous experience.

Appendix 1

Table A1.1: Responses to questions relating to Understanding of Inquiry, based on individual teacher experience in IBSE (SD, D, U, A, SA abbreviate for strongly disagree, disagree, uncertain, agree, strongly agree).

Statement item	Group	SD/D	U	A/SA	N/D	Mean
11. I don't fully understand inquiry based science education	BE	58.1	20.2	20.7	1.0	2.5
	SE	80.7	13.8	5.5	0.0	2.1
	VE	50.0	0.0	50.0	0.0	3.0
	Total	**61.3**	**17.2**	**14.2**	**7.4**	**2.4**
12. I don't fully understand my role as a teacher in an inquiry classroom	BE	63.5	18.2	17.7	0.5	2.4
	SE	81.7	9.2	8.3	0.9	2.1
	VE	50.0	0.0	50.0	0.0	3.0
	Total	**64.6**	**14.2**	**13.9**	**7.4**	**2.3**
13. I don't fully understand the role of the students in an inquiry classroom	BE	70.0	17.7	11.8	0.5	2.2
	SE	84.4	11.9	3.7	0.0	2.0
	VE	50.0	0.0	50.0	0.0	2.5
	Total	**69.8**	**14.2**	**9.0**	**7.1**	**2.1**

Table A1.2: Responses to questions relating to Attitude to Inquiry, based on individual teacher experience in IBSE (SD, D, U, A, SA abbreviate for strongly disagree, disagree, uncertain, agree, strongly agree).

Statement item	Group	SD/D	U	A/SA	N/D	Mean
14. I think inquiry takes up too much classroom time for me to implement.	BE	36.0	30.5	32.5	1.0	2.9
	SE	45.0	26.6	27.5	0.9	2.8
	VE	50.0	50.0	0.0	0.0	2.5
	Total	**37.3**	**30.0**	**28.3**	**4.4**	**2.9**
15. The use of inquiry is appropriate to achieving the aims of the curriculum.	BE	9.9	31.0	56.2	3.0	3.5
	SE	11.0	16.5	67.9	4.6	3.8
	VE	50.0	0.0	50.0	0.0	3.5
	Total	**9.3**	**25.6**	**55.3**	**9.8**	**3.6**
16. Inquiry based teaching is only suitable for very capable students.	BE	63.1	20.7	12.8	3.4	2.3
	SE	50.5	27.5	18.3	3.7	2.6
	VE	50.0	50.0	0.0	0.0	2.0
	Total	**59.7**	**22.9**	**14.2**	**3.3**	**2.4**

Table A1.3: Responses to questions relating to Industrial Links, based on individual teacher experience in IBSE (SD, D, U, A, SA abbreviate for strongly disagree, disagree, uncertain, agree, strongly agree).

Statement item	Group	SD/D	U	A/SA	N/D	Mean
37. I want my students to know about the latest developments and applications of science and engineering.	BE	5.9	13.8	76.8	3.4	4.0
	SE	7.3	20.2	67.0	5.5	3.8
	VE	0.0	0.0	100	0.0	4.0
	Total	**6.0**	**14.4**	**69.2**	**10.4**	**3.9**
38. I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom.	BE	11.8	36.5	46.3	5.4	3.4
	SE	11.9	29.4	52.3	6.4	3.5
	VE	0.0	50.0	50.0	0.0	4.0
	Total	**10.6**	**33.2**	**47.7**	**8.4**	**3.5**
39. I often show students the relevance of science in industry.	BE	5.4	21.7	70.4	2.5	3.9
	SE	7.3	7.3	79.8	5.5	4.0
	VE	0.0	0.0	100	0.0	4.5
	Total	**5.4**	**14.7**	**70.0**	**9.8**	**3.9**
40. My students understand the importance of science and technology for our society.	BE	0.5	4.4	92.1	3.0	4.3
	SE	4.6	8.3	81.7	5.5	4.1
	VE	0.0	0.0	100	0.0	5.0
	Total	**3.5**	**5.7**	**87.5**	**3.3**	**4.2**
41. If I had more information about industrial processes, I would use it in my teaching.	BE	9.9	33.0	53.7	3.4	3.6
	SE	11.0	15.6	67.9	5.5	3.8
	VE	0.0	0.0	100	0.0	4.5
	Total	**9.8**	**25.3**	**54.5**	**10.4**	**3.7**

Table A1.4: Responses to questions relating to Practice in the Classroom, based on individual teacher experience in IBSE (SD, D, U, A, SA abbreviate for strongly disagree, disagree, uncertain, agree, strongly agree).

Statement item	Group	SD/D	U	A/SA	N/D	Mean
42. If a student investigation leads to an unexpected result I always tell the students the right answer/result.	BE	27.6	29.6	42.9	0.0	3.2
	SE	49.5	13.8	34.9	1.8	2.9
	VE	0.0	0.0	100	0.0	4.0
	Total	**36.5**	**23.7**	**38.7**	**1.1**	**3.1**
44. I am unsure how to ask students higher order questions that promotes thinking.	BE	47.3	22.7	30.0	0.0	2.8
	SE	51.4	14.7	32.1	1.8	3.3
	VE	50.0	50.0	0.0	0.0	2.5
	Total	**46.0**	**19.9**	**30.0**	**4.1**	**2.8**
45. I have sufficient knowledge of science to implement an inquiry lesson effectively	BE	18.7	46.8	34.0	0.5	3.1
	SE	22.9	24.8	50.5	1.8	3.3
	VE	0.0	50.0	50.0	0.0	4.0
	Total	**19.9**	**36.8**	**39.0**	**4.4**	**3.2**

Table A1.5: Responses to questions relating to Personal Skills in the Inquiry Classroom, based on individual teacher experience in IBSE (SD, D, U, A, SA abbreviate for strongly disagree, disagree, uncertain, agree, strongly agree).

Statement item	Group	SD/D	U	A/SA	N/D	Mean
43. I find it difficult to manage a classroom where each student	BE	40.4	21.7	35.5	2.5	2.9
	SE	32.1	23.9	38.5	5.5	3.1

group is doing different activities.	VE	50.0	50.0	0.0	0.0	2.5
	Total	**37.3**	**22.1**	**34.1**	**6.5**	**2.9**
46. I am uncomfortable with teaching areas of science that I have limited knowledge of.	BE	12.3	10.8	75.4	1.5	3.8
	SE	22.0	7.3	67.9	2.8	3.6
	VE	50.0	0.0	50.0	0.0	3.0
	Total	**14.7**	**8.7**	**68.1**	**8.4**	**3.7**
47. If I don't know the answers to students' questions I feel inadequate as a teacher.	BE	47.3	13.3	38.4	1.0	2.9
	SE	60.6	15.6	22.0	1.8	2.6
	VE	50.0	0.0	50.0	0.0	3.0
	Total	**51.2**	**13.6**	**30.5**	**4.6**	**2.7**
48. I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself.	BE	11.8	7.4	76.8	3.9	3.9
	SE	12.8	8.3	72.5	6.4	3.9
	VE	0.0	0.0	100	0.0	4.5
	Total	**12.3**	**8.2**	**71.9**	**7.6**	**3.8**

Appendix 2

Table A2.1 Understanding of Inquiry Means Before/After workshop

Blue shading and text signifies significant differences in mean at 95% level based on Wilcoxon Signed Rank.

	A	B	C	D	E	J	K
11. I don't fully understand inquiry based science education	2.42/ 2.44	2.12/ 1.95	3.40/ 1.83	1.94/ 2.15	2.19/ 1.89	2.31/ 2.31	2.50/2 .17
12. I don't fully understand my role as a teacher in an inquiry classroom	2.27/ 2.39	2.16/ 1.71	3.18/ 1.85	2.00/ 2.00	2.06/ 1.81	2.23/ 2.27	2.83/2 .50
13. I don't fully understand the role of the students in an inquiry classroom	2.15/ 2.33	1.98/ 1.65	3.00/ 1.85	1.70/ 1.82	2.03/ 1.81	2.15/ 2.19	2.17/2 .00

	Whole Group	BE	SE
11. I don't fully understand inquiry based science education	2.42/2.07	2.61/2.08	2.00/2.04
12. I don't fully understand my role as a teacher in an inquiry classroom	2.35/1.99	2.50/1.99	2.03/1.99
13. I don't fully understand the role of the students in an inquiry classroom	2.18/1.92	2.32/1.90	1.88/1.96

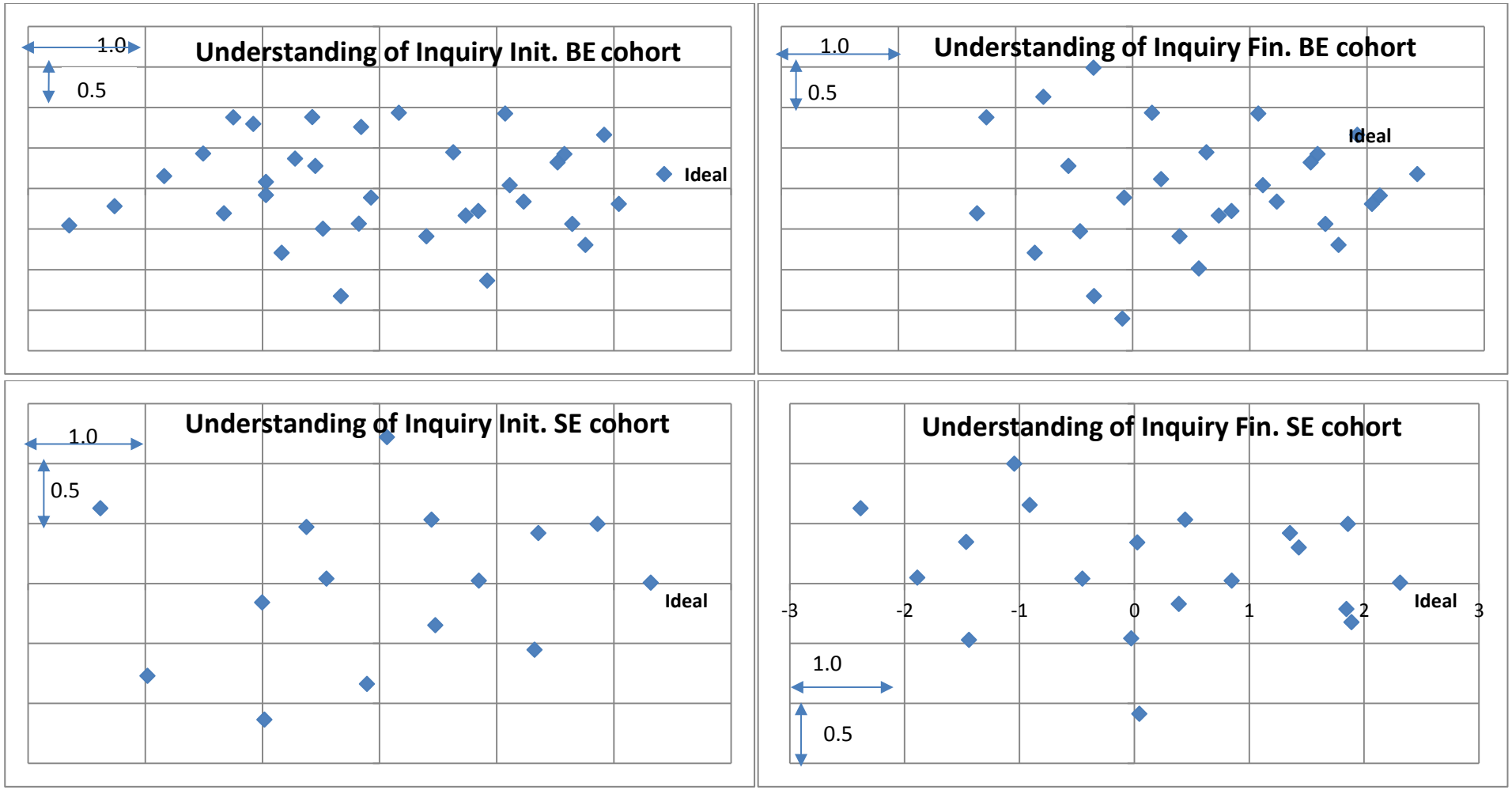

Figure A2.1: MDS plots for Understanding of Inquiry for BE and SE cohorts before and after TEP

Table A2.2 Attitude to Inquiry Means Before/After workshop

Blue shading and text signifies significant differences in mean at 95% level based on Wilcoxon Signed Rank.

	A	B	C	D	E	J	K
14. I think inquiry takes up too much classroom time for me to implement.	2.97/ 3.00	2.70/ 2.74	3.13/ 2.48	2.39/ 2.42	2.56/ 3.64	2.73/ 2.73	3.00/2 .50
15. The use of inquiry is appropriate to achieving the aims of the curriculum	3.48/ 3.58	3.65/ 3.56	3.60/ 4.08	3.88/ 3.73	3.89/ 3.60	3.16/ 3.08	3.33/3 .17
16. Inquiry based teaching is only suitable for very capable students.	3.24/ 2.70	1.91/ 1.84	2.58/ 2.13	2.06/ 1.88	2.63/ 2.37	2.31/ 2.19	1.67/2 .33

	Whole Group	BE	SE
14. I think inquiry takes up too much classroom time for me to implement.	2.93/2.82	2.91/2.67	2.96/3.16
15. The use of inquiry is appropriate to achieving the aims of the curriculum	3.63/3.62	3.60/3.69	3.70/3.49
16. Inquiry based teaching is only suitable for very capable students.	2.38/2.17	2.26/2.07	2.66/2.38

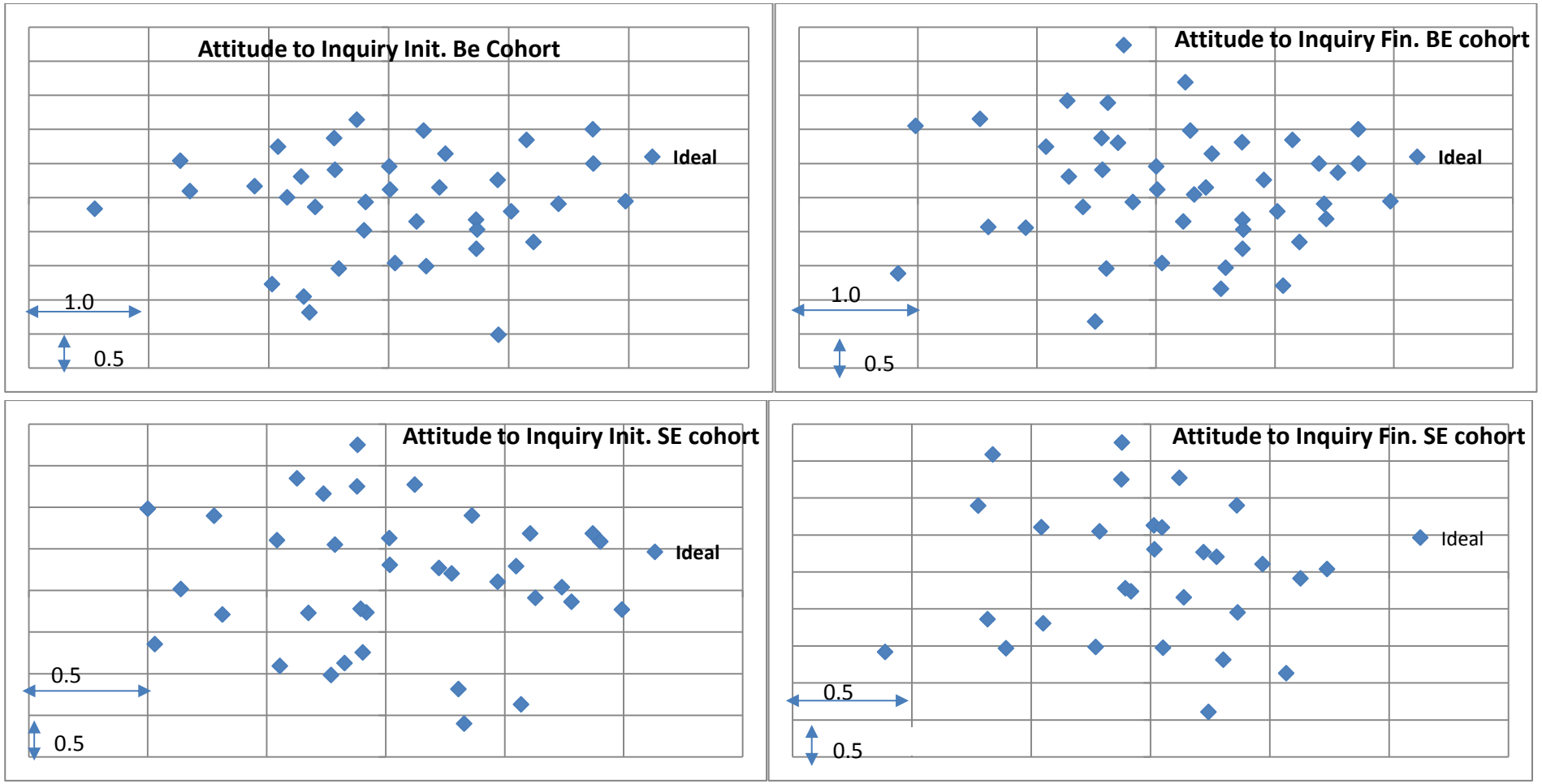

Figure A2.2: MDS plots for Attitude to Inquiry for BE and SE cohorts before and after TEP

Table A2.3 Industrial Links Means Before/After workshop

Blue shading and text signifies significant differences in mean at 95% level based on Wilcoxon Signed Rank.

Industrial Links	A	B	C	D	E	J	K
37. I want my students to know about the latest developments and applications of science and engineering	4.12/ 3.91	3.76/ 3.86	4.43/ 4.20	3.85/ 4.30	3.22/ 3.64	3.60/ 3.77	3.50/3 .83
38. I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom	3.56/ 3.97	3.18/ 3.41	3.83/ 4.15	3.16/ 3.91	3.03/ 3.17	3.50/ 3.88	3.50/3 .83
39. I often show students the relevance of science in industry	4.16/ 3.73	3.98/ 3.30	3.50/ 3.53	3.55/ 3.69	3.69/ 2.39	4.19/ 3.16	4.17/3 .33
40. My students understand the importance of science and technology for our society	4.32/ 3.45	4.32/ 3.36	4.43/ 3.65	4.12/ 3.78	3.47/ 3.47	4.54/ 3.26	4.67/3 .50
41. If I had more information about industrial processes, I would use it in my teaching	4.08/ 4.06	3.78/ 3.63	3.50/ 3.60	3.67/ 4.21	3.08/ 3.39	3.68/ 3.35	3.83/3 .17

Industrial Links	Whole Group	BE	SE
37. I want my students to know about the latest developments and applications of science and engineering	3.83/3.95	3.95/4.04	3.53/3.75
38. I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom	3.37/3.74	3.38/3.79	3.34/3.63
39. I often show students the relevance of science in industry	3.82/3.30	3.81/3.35	3.84/3.19
40. My students understand the importance of science and technology for our society	4.20/3.51	4.30/3.49	3.97/3.54
41. If I had more information about industrial processes, I would use it in my teaching	3.61/3.69	3.60/3.73	3.65/3.60

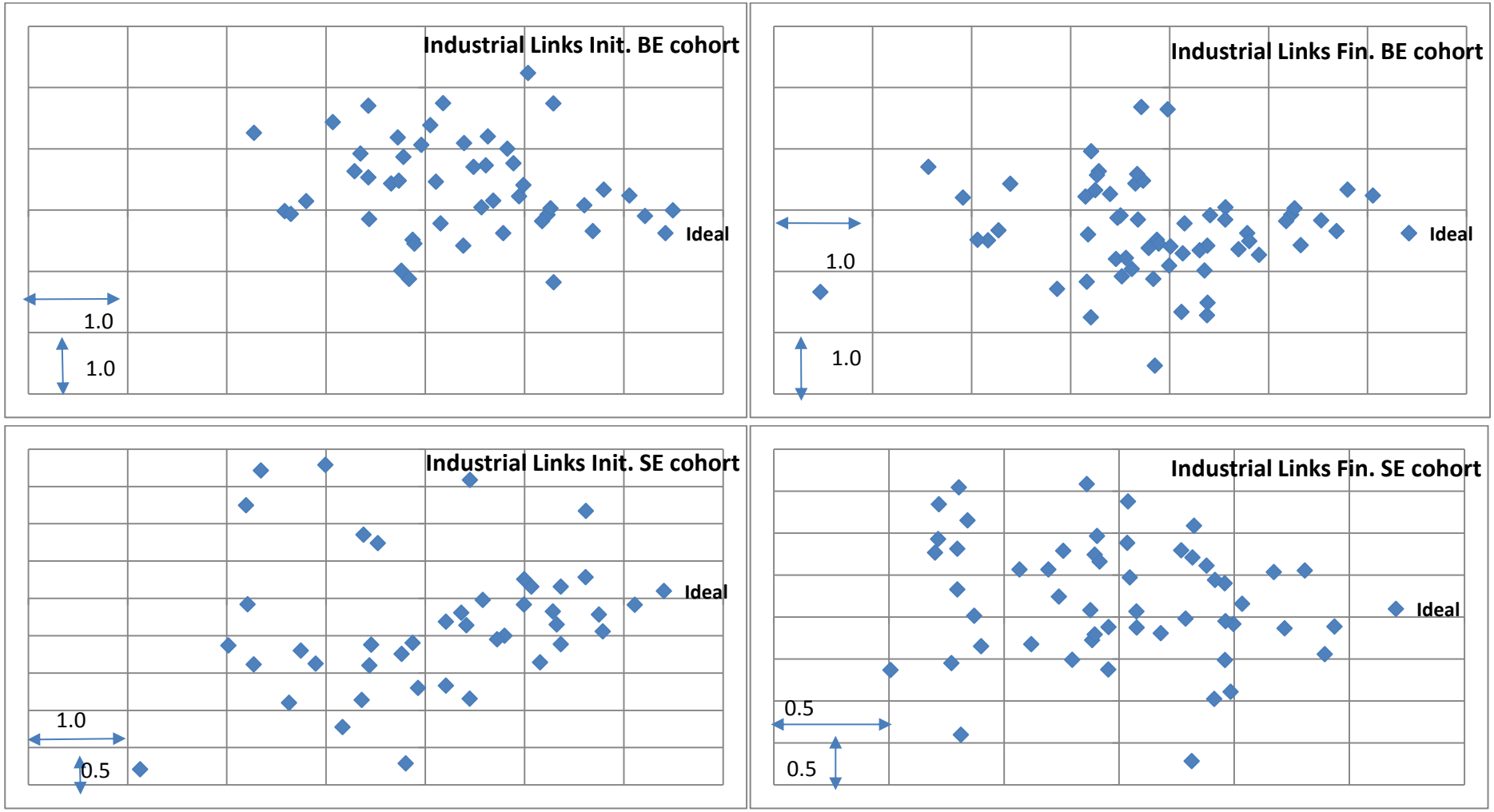

Figure A2.3: MDS plots for Industrial Links for BE and SE cohorts before and after TEP

Table A2.4 Practice Means Before/After workshop

Blue shading and text signifies significant differences in mean at 95% level based on Wilcoxon Signed Rank.

Practice in the Inquiry Classroom	A	B	C	D	E	J	K
42. If a student investigation leads to an unexpected result I always tell the students the right answer/result	2.36/ 3.12	3.83/ 3.73	2.93/ 2.60	3.06/ 3.36	3.69/ 3.03	3.65/ 3.50	3.67/3 .17
44. I am unsure how to ask students higher order questions that promotes thinking	2.55/ 2.52	2.80/ 2.47	2.18/ 1.93	2.82/ 2.97	3.39/ 3.14	3.00/ 2.92	2.50/2 .17
45. I have sufficient knowledge of science to implement an inquiry lesson effectively	3.30/ 3.58	3.32/ 3.76	2.98/ 3.55	3.24/ 3.39	2.53/ 3.72	3.19/ 3.27	2.33/3 .17

Practice in the Inquiry Classroom	Whole Group	BE	SE
42. If a student investigation leads to an unexpected result I always tell the students the right answer/result	3.10/3.21	3.21/3.29	2.85/3.03
44. I am unsure how to ask students higher order questions that promotes thinking	2.76/2.56	2.68/2.53	2.95/2.63
45. I have sufficient knowledge of science to implement an inquiry lesson effectively	3.07/2.80	3.05/3.50	3.09/3.67

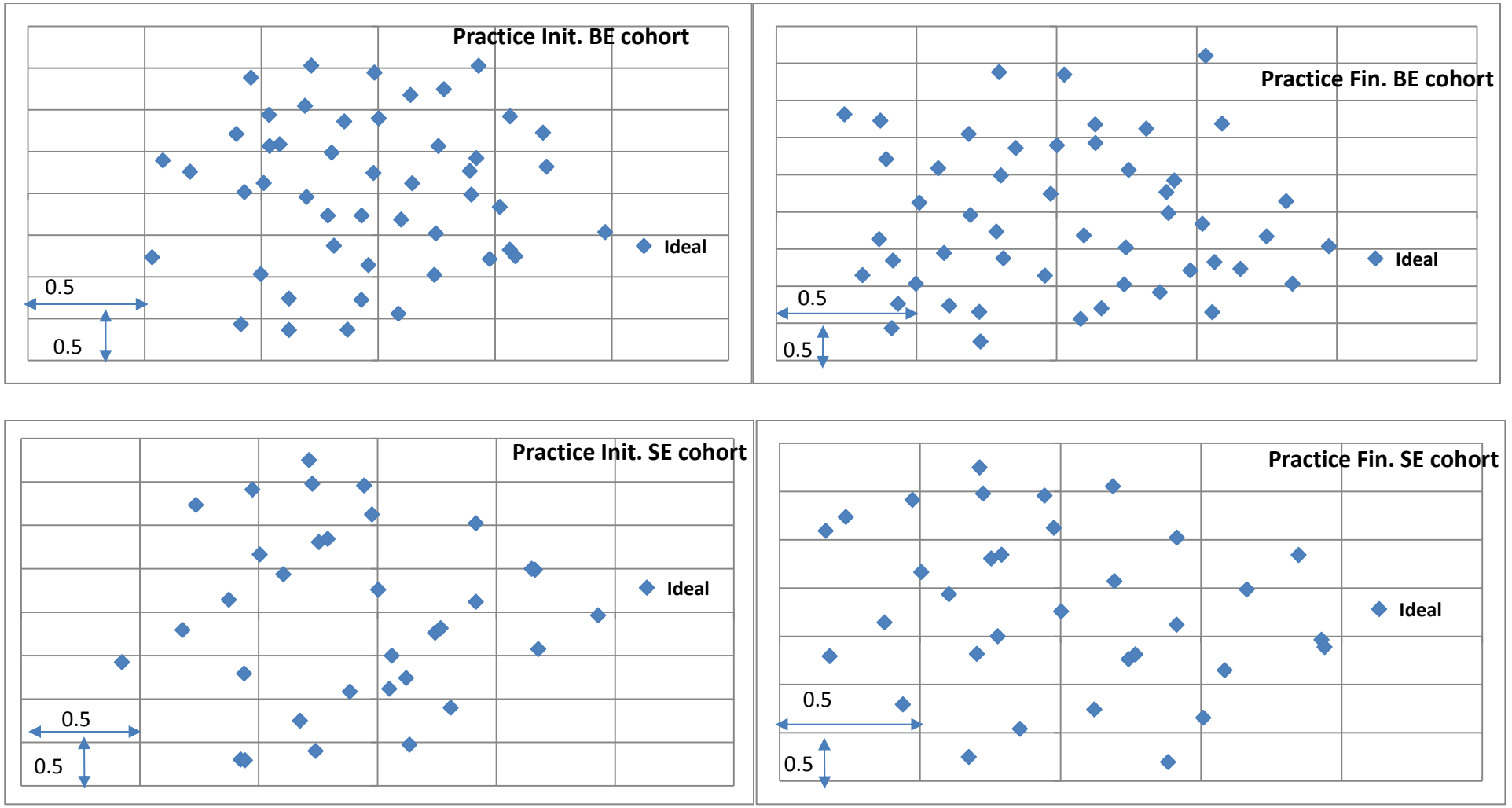

Figure A2.4: MDS plots for Practice in Inquiry Classroom for BE and SE cohorts before and after TEP

Table A2.5 Skills Means Before/After workshop

Blue shading and text signifies significant differences in mean at 95% level based on Wilcoxon Signed Rank.

Personal Skills in the Inquiry Classroom	A	B	C	D	E	J	K
43. I find it difficult to manage a classroom where each student group is doing different activities	3.32/ 3.28	2.76/ 2.68	2.73/ 2.48	2.82/ 2.91	3.33/ 3.44	2.62/ 2.50	2.33/2 .33
46. I am uncomfortable with teaching areas of science that I have limited knowledge of	3.53/ 3.42	3.02/ 2.86	4.26/ 3.93	3.70/ 3.82	3.89/ 3.66	4.04/ 3.69	3.50/4 .17
47. If I don't know the answers to students questions I feel inadequate as a teacher	3.27/ 2.76	2.78/ 2.86	3.00/ 2.65	3.36/ 3.42	2.33/ 2.42	1.96/ 1.73	2.17/1 .83
48. I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself	3.72/ 3.39	3.80/ 3.81	4.15/ 3.35	3.66/ 4.15	4.03/ 4.03	3.81/ 3.73	3.50/2 .50

Personal Skills in the Inquiry Classroom	Whole Group	BE	SE
43. I find it difficult to manage a classroom where each student group is doing different activities	2.90/2.86	2.81/2.71	3.10/3.19
46. I am uncomfortable with teaching areas of science that I have limited knowledge of	3.71/3.56	3.81/3.64	3.50/3.36
47. If I don't know the answers to students questions I feel inadequate as a teacher	2.79/2.65	2.89/2.77	2.59/2.40
48. I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself	3.87/3.71	3.85/3.72	3.90/3.68

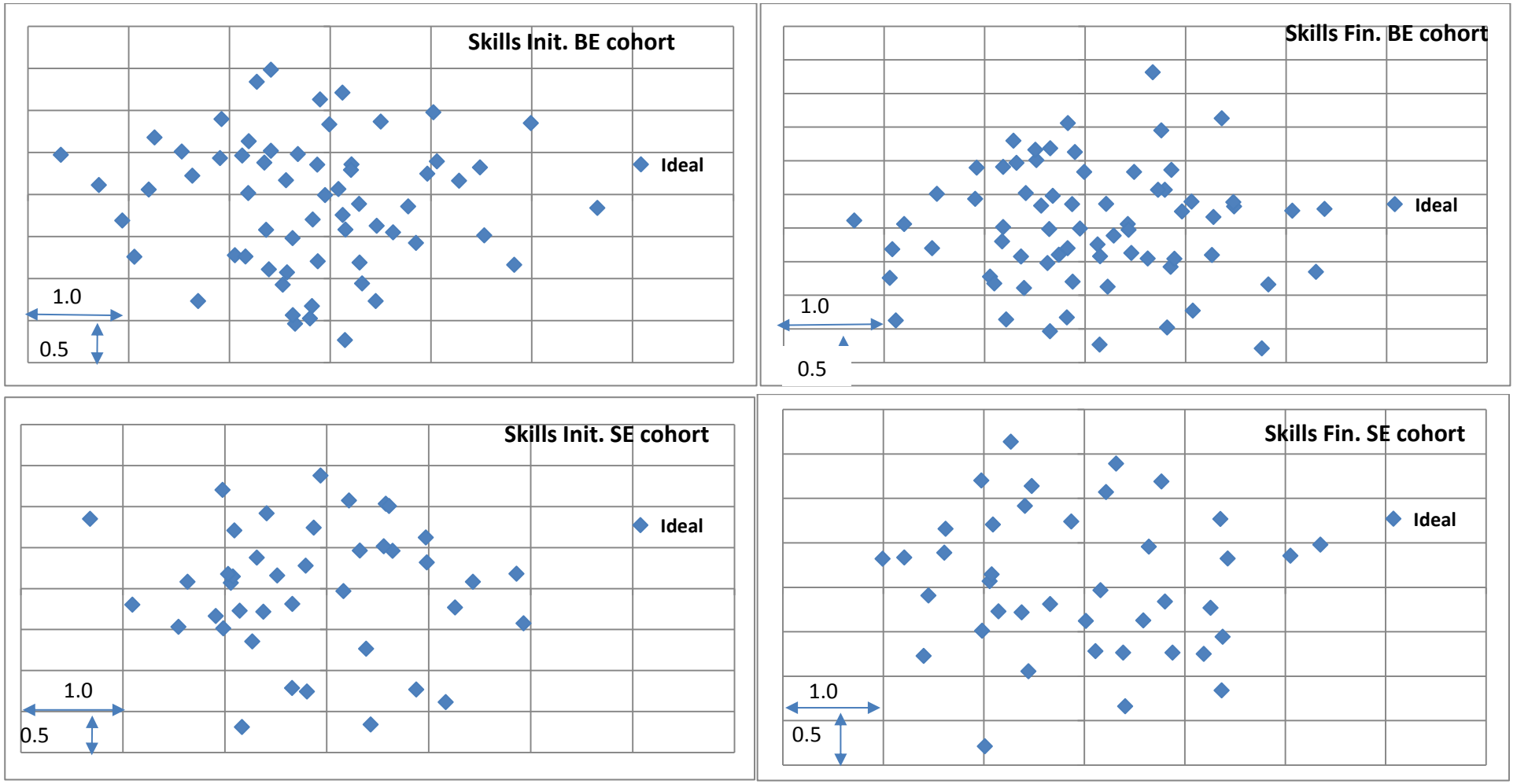

Figure A2.5 MDS Plots for Inquiry Skills for BE and SE cohorts before and after TEP

Appendix 3

Gender Effects: Summary Table

SA*, A*, U*, D*, SD* = strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal

Understanding of Inquiry	BE Cohort				SE Cohort			
	M Before	M After	F Before	F After	M Before	M After	F Before	F After
SA*	12.5%	15%	15.6%	23.9%	9.1%	22.7%	32.6%	28.3%
A*	30%	50%	41.3%	55%	59.1%	40.9%	52.2%	54.3%
U*	25%	22.5%	20.2%	13.8%	18.2%	13.6%	13%	13%
D*	12.5%	10%	20.2%	7.3%	13.6%	22.7%	0%	2.2%
SD*	20%	2.5%	2.8%	0%	0%	0%	2.2%	2.2%

Attitude to Inquiry	BE Cohort				SE Cohort				
	M Before	M After	F Before	F After	M Before	M After	F Before	F After	M Before
SA*	5%	7.5%	11.9%	9.2%	0%	0%	10.9%	2.2%	0%
A*	12.5%	32.5%	22%	43.1%	18.2%	40.9%	23.9%	17.4%	18.2%
U*	52.5%	32.5%	52.3%	33%	36.4%	50%	41.3%	43.5%	36.4%
D*	30%	20%	12.8%	14.7%	45.5%	9.1%	21.7%	34.8%	45.5%
SD*	0%	7.5%	0.9%	0%	0%	0%	2.2%	2.2%	0%

Industrial Links	BE Cohort				SE Cohort			
	M Before	M After	F Before	F After	M Before	M After	F Before	F After
SA*	10.0%	7.5%	1.8%	0.9%	0%	0%	2.2%	0%
A*	25.0%	12.5%	8.3%	4.6%	9.1%	18.2%	10.9%	8.7%
U*	35.0%	32.5%	37.6%	34.9%	54.5%	50%	32.6%	17.4%
D*	25.0%	30.0%	41.3%	41.3%	13.6%	18.2%	23.9%	41.3%
SD*	5.0%	17.5%	11.0%	18.3%	22.7%	13.6%	30.%	32.6%

Practice in the Inquiry Classroom	BE Cohort				SE Cohort			
	M Before	M After	F Before	F After	M Before	M After	F Before	F After

SA*	2.5%	2.5%	0%	2.8%	4.5%	13.6%	0%	2.2%
A*	10%	27.5%	10.1%	14.7%	22.7%	22.7%	10.9%	8.7%
U*	65%	47.5%	53.2%	49.5%	45.5%	40.9%	43.5%	67.4%
D*	20%	22.5%	35.8%	28.4%	27.3%	22.7%	43.5%	21.7%
SD*	2.5%	0%	0.9%	4.6%	0%	0%	2.2%	0%

Personal Skills	**BE Cohort**				**SE Cohort**			
	M Before	**M After**	**F Before**	**F After**	**M Before**	**M After**	**F Before**	**F After**
SA*	2.5%	0%	1.8%	0%	0%	0%	0%	0%
A*	0%	7.5%	0%	3.7%	0%	9.1%	0%	2.2%
U*	15%	27.5%	10.1%	16.5%	31.8%	27.3%	21.7%	26.1%
D*	52.5%	35%	34.9%	32.1%	40.9%	36.4%	21.7%	21.7%
SD*	30%	30%	53.2%	47.7%	27.3%	27.3%	56.5%	50%

Appendix 4

PRESERVICE TEACHER QUESTIONNAIRE - B

This questionnaire examines inquiry based teaching as part of the ESTABLISH project. Your participation is greatly appreciated.

Section A: Background Information

1. Name:_____ **2. Year in University:_____**

3. University/Institution:_____

4. Previous Teaching Experience (Weeks spent teaching): _____

5. In your experience with inquiry based teaching do you consider yourself: (Tick appropriate box)

- A complete beginner ☐
- To have some experience ☐
- Very experienced ☐

Section B. My Views of Inquiry

Please indicate the level of your agreement with each of the following statements.

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
6. I don't fully understand inquiry-based science education					
7. I don't fully understand my role as a teacher in an inquiry classroom					
8. I don't fully understand the role of the students in an inquiry classroom					
9. I think inquiry takes up too much classroom time for me to implement.					
10. The use of inquiry is appropriate to achieving the aims of the curriculum.					
11. Inquiry-based teaching is only suitable for very capable students.					
12. Inquiry will never be my main teaching method					

13. In your opinion, what are the benefits of using inquiry based teaching?

_____
_____
_____
_____
_____
_____

14. If you have used inquiry, what percentage of your teaching time did you spend using it?

_____
_____
_____

15. Outline what you did when using inquiry based teaching.

_____
_____
_____
_____
_____
_____
_____
_____
_____
__

16. Outline what your students did when at inquiry lessons.

_____
_____
_____
_____
_____
_____
_____
_____

Section C. Industrial Content Knowledge and Authentic Experiences

Please indicate the level of your agreement with each of the following statements.

In my opinion, when teaching science,	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
17. I want my students to know about the latest developments and applications of science and engineering.					
18. I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom.					
19. I often showed students the relevance of science in industry					
20. My students understood the importance of science and technology for our society.					
21. If I had more information about industrial processes, I would use it in my teaching.					

Section D. Teaching science

Please indicate the level of your agreement with each of the following statements.

	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
22. If a student investigation leads to an unexpected result I always tell the students the right answer/result.					
23. I find it difficult to manage a classroom where each student group is doing different activities.					
	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
24. I am unsure how to ask students higher order questions that promotes thinking.					
25. I have sufficient knowledge of science to implement an inquiry lesson effectively					
26. I am uncomfortable with teaching areas of science that I have limited knowledge of.					
27. If I don't know the answers to students questions I feel inadequate as a teacher					
28. I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself.					

Section E: Challenges in Inquiry Teaching

29. Teachers may face a variety of challenges in implementing inquiry-based teaching. Please **rank** your TOP THREE challenges, as they apply to you, starting with 1 as your biggest concern:

Lack of time to implement inquiry	
Curriculum constraints	
Lack of equipment/assistance in school laboratories	
Lack of supportive school management	
Classroom management issues	
Limited scientific content knowledge to use inquiry effectively	
Limited knowledge of teaching by inquiry	
Assessment methods for inquiry	
Limited knowledge of ICT as used in inquiry	
Other (Please list):	
None of the above – I teach by inquiry	