WP4| D4.5

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D4.5 Report on the final profile of in-service science teachers' attitude and understanding of IBSE

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Name of Coordinator: Dr. Eilish McLoughlin

Name of lead partner for this deliverable: DCU

A. Background to this report

This report is a deliverable of Work Package 4 (WP4) 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 4.5 by presenting a report on the final profile of in-service teachers' understanding of and attitude to inquiry based science education.

Report prepared by Odilla Finlayson, Eilish McLoughlin, Deirdre McCabe, Leeanne Hinch, Sarah Brady, CASTeL, Dublin City University, Dublin

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For further information regarding ESTABLISH please contact:

Dr. Sarah Brady (ESTABLISH project manager)

Email: sarah.brady@dcu.ie

ESTABLISH website: http://www.establish-fp7.eu

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

D4.5 Final Profile of in-service science teachers' attitudes and understanding of IBSE

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EXECUTIVE SUMMARY

The ESTABLISH project focusses on developing and implementing inquiry based workshops (Teacher Education Programme, TEP) for teachers, where the participants can increase their knowledge of and implementation skills in inquiry based teaching. Each of the beneficiaries of ESTABLISH have run TEPs for their teachers. The 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. Additional programme elements include Argumentation, ICT, Research and Design Projects, and Assessment of IBSE.

This report outlines the initial profile of the teachers attending the TEPs and the change in these teachers following the TEP, in terms of a number of attributes, namely:

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

The initial profile is based on 458 teachers attending the TEPs across 13 institutions. The overall sample has a spread of age, teaching experience and experience with inquiry based science education (IBSE). Half of the teachers were in 36-50 year age group and three-quarters were female, with females out numbering males in most cohorts. The majority (88%) were teaching in mixed gender schools. In terms of teaching experience generally, a third of the overall group had 10 years or less teaching experience, a third had 11-20 years and the remaining third had over 20 years experience. With regard to experience with IBSE, the teachers rated themselves as a beginner (48%), having some experience (45%) or very experienced (7%). Experience with IBSE did not correlate with the age of the teacher or years of teaching experience. Many of the attributes of the teachers across all the countries depended more on their stated experience level, rather than the particular country cohort; therefore while some cohorts show more positive attributes towards inquiry, they generally consist of teachers more experienced in IBSE.

The initial profile of the teachers strongly related to their stated experience level with IBSE with those with some or very experienced with IBSE showing a greater understanding of inquiry and the role of teachers and students in an inquiry classroom, than the beginner cohort. In terms of reported barriers to implementing inquiry such as time-pressures and lack of suitability for all student abilities, the beginner cohort were more uncertain towards overcoming these barriers while experienced teachers felt that these issues were not so important. With regard to industrial links, almost all teachers value a broader view of science in the classroom, stating that they want their 'students to know about the latest developments and applications of science and engineering'.

There are large differences seen with classroom practice, with the beginner cohort finding practices associated with IBSE more difficult – such as dealing with 'right answer/result' of an investigation, asking higher order questions that promote thinking and managing a classroom where each student group is doing different activities. Regardless of experience level with inquiry, there were many teachers who felt uncomfortable with teaching areas of science that they had limited knowledge of or asking questions, where they were unsure of the answer.

Following the TEP, almost all cohorts have increased their understanding of inquiry and their understanding of the roles of teacher and student in an inquiry classroom, with the biggest increase by those who classify themselves as beginners in IBSE. Attitudes to inquiry have also shifted towards overcoming the barriers often associated with IBSE, with again the biggest shift by the beginner cohort. This seems to indicate that the

ESTABLISH TEP programme is useful to help teachers to recognise the benefits for all students of inquiry approaches.

Small shifts in terms of Industrial links were evident by most of the teacher cohorts after the TEP, with similar shifts for both beginner and experienced teachers. The beginner cohort agreed more significantly that they wanted their students to know about the latest developments and applications of science and engineering and that they could use more information about industrial process in their teaching. Many cohorts changed their opinion of their abilities to ask higher order questions that promote thinking in students and also of their confidence in their own science knowledge, after the TEP. With regards to teachers' skills, there is a general positive shift after the TEP towards attitudes that are desirable in an inquiry classroom.

All of the main shifts in attributes of inquiry have been analysed in terms of gender; within the beginner group, the male cohort seem to have moved in greater numbers towards the ideal inquiry responses than the female group for each of the attributes; the gender shifts are not as clear for those with experience. However, the gender effects seem to be of a secondary significance compared to the experience level; i.e. the shifts in attributes seem to depend primarily on the prior experience of the teachers with IBSE.

While some changes in attributes of inquiry relate more to particular country cohorts, the main shifts in attributes can be related to the prior experience level of the teachers. The ESTABLISH In-service teacher education programme has increased the understanding and attitudes of in-service teachers towards inquiry and this shift is greater for those who considered themselves as beginners with inquiry. The ESTABLISH programme has also increased awareness of industrial links and inquiry practices in the classroom. The ESTABLISH programme was a minimum of 10 hours face-to-face training and particular cohorts had emphasis on different parts of the programme. Further details, in the form of case studies are given in D4.6.

Profile of Teacher Change - in-service teachers

INTRODUCTION

The ESTABLISH project focusses on developing and implementing inquiry based workshops (Teacher Education Programme, TEP) for teachers, where the participants can increase their knowledge of and implementation skills in inquiry based teaching. Each of the beneficiaries of ESTABLISH have run TEP for their teachers. The 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. Additional programme elements include Argumentation, ICT, Research and Design Projects, and Assessment of IBSE. To determine the effect of this programme on teachers in terms of their understanding and attitudes towards inquiry, an evaluation tool (Appendix 4) was developed to determine the teacher's attitudes before and after the TEP. Specific focus is placed on the change in teachers' attitudes towards inquiry, their attitude towards the relevance of industrial links and their understanding of inquiry. Cognisance was also taken of any gender effects in Section 3.

BACKGROUND

An evaluation tool was developed in the form of a paper questionnaire (see Appendix 4, In-service Teacher Questionnaire A), which was distributed to teachers at the start of the TEP. A second questionnaire (Appendix 4, In-service Teacher Questionnaire B) was distributed to the same teachers either at the end of the series of workshops or some months later. While the TEP implemented in each country followed the guidelines agreed in ESTABLISH, they did differ from each other e.g. in the duration of the programme (all >10hrs), the concentration of the workshop (e.g. summer school, series of individual workshops) and in emphasis (depending on the experience level of the teachers attending). These differences and similarities are discussed in detail in D4.6.

This document discusses the changes that are evident in the responses to the questionnaires, comparing responses at the beginning of the first workshop and after the TEP. The report is structured into four sections, where Section 1 presents an overview of the cohort of 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, 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 458 teachers attending the TEP, organised by 13 institutions, completed the first questionnaire. The overall sample has a spread of age, teaching experience and experience with inquiry based science education (IBSE). Table 1 gives an overview of the teacher cohort. Note that particular cohorts of teachers are identifiable through their code, as shown in Table 1. Half of the teachers were in 36-50 year age group and three-quarters were female. Most of them were teaching in mixed gender schools, with only four countries having teachers involved in single-sex schools (countries A, C, D, I). In most cases, female teachers outnumbered male teachers, with the exception of two countries, H and J.

In terms of teaching experience generally, a third of the overall group had 10 years or less teaching experience, a third had 11-20 years and the remaining third had over 20 years-experience.

In completing the questionnaires, the teachers rated themselves in terms of their experience with IBSE, either as a beginner (BE), having some experience (SE) or very experienced (VE). Using this rating, the overall cohort consisted of 48% BE, 45% with SE and 7% VE teachers. While the SE group have individuals from each country, the majority of the BE group comes from three countries B, C and E. Note that experience in IBSE is not related to the age of the teacher or years of teaching experience (see Figure 1).

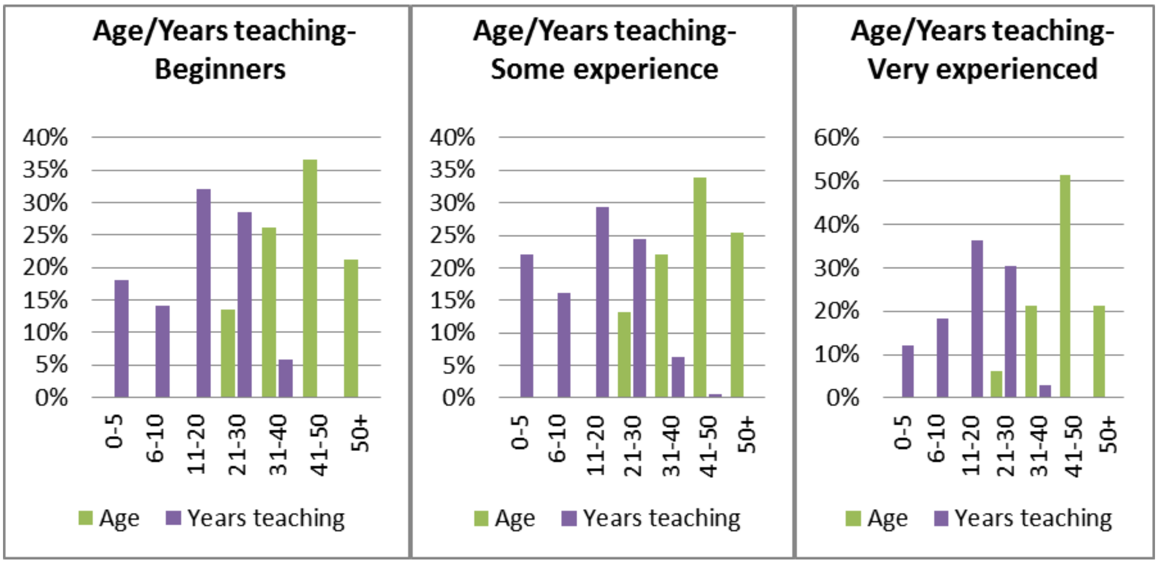


Figure 1: Age distribution and years of teaching experience for those rated as Beginners (BE), Some experience (SE) and Very experienced (VE) in inquiry

Partner	Code	Number of Teachers	Age range/ %*			Years of teaching experience/ %*					Gender/ %*		Type of School/ %*			Experience Level/ %*			Matched Pre and post/%
			20-35	36-50	>50	0-5	6-10	11-20	21-30	>30	M	F	All Boys	All Girls	Mixed	BE	SE	VE	
DCU	A	91	48.4	33.0	6.6	41.8	14.3	20.9	16.5	3.3	18.7	81.3	9.9	19.8	69.2	40.7	50.5	8.8	9.9
CUNI	B	70	28.6	57.1	11.4	25.7	11.4	37.1	22.9	2.9	5.7	94.3	0.0	0.0	100	82.9	17.1	0.0	94.3
UNIPA	C	59	3.4	59.3	37.3	1.7	3.4	37.3	49.2	8.5	28.8	71.2	11.9	0.0	88.1	86.4	13.6	0.0	91.5
JU	D	37	10.8	56.8	32.4	5.4	10.8	35.1	43.2	2.7	8.1	91.9	2.7	2.7	94.6	43.2	51.4	5.4	45.9
UPJS	E	33	27.3	48.5	24.2	6.1	18.2	30.3	33.3	12.1	9.1	90.9	0.0	0.0	100	100	0.0	0.0	100
UTARTU	F	30	30.0	36.7	33.3	16.7	16.7	20.0	26.7	20.0	20.0	80.0	0.0	0.0	100	23.3	73.3	3.3	63.3
MaH	G	28	14.3	57.1	25	3.6	28.6	35.7	25.0	7.1	17.9	78.6	0.0	0.0	100	0.0	64.3	35.7	21.4
CMA	H	19	10.5	42.1	47.4	26.3	5.3	15.8	21.1	26.3	68.4	31.6	0.0	0.0	100	31.6	63.2	5.3	52.6
AL	I	21	14.3	71.4	9.5	4.8	0.0	57.1	38.1	0.0	38.1	61.9	33.3	33.3	19.0	33.3	66.7	0.0	90.5
IPN	J	13	46.2	23.1	23.1	46.2	15.4	38.5	0.0	0.0	69.2	30.8	0.0	0.0	100	15.4	84.6	0.0	0.0
MLU	K	7	14.3	57.1	28.6	14.3	14.3	28.6	42.9	0.0	42.9	57.1	0.0	0.0	100	14.3	42.9	42.9	0.0
UC	L	32	3.1	65.6	31.3	25.0	40.6	25.0	6.3	3.1	28.1	71.9	0.0	0.0	100	6.3	81.3	12.5	0.0
UmU	M	18	11.1	50.0	38.9	0.0	38.9	38.9	22.2	0.0	33.3	66.7	0.0	0.0	100	5.6	72.2	22.2	0.0
TOTAL		458	23.4	50.0	22.9	19.2	15.3	31.2	26.9	6.1	22.5	77.3	5.2	5.7	88.2	48.3	44.5	7.2	50.9

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 workshop 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 configuration.

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 their role as a teacher and the role of the students in the inquiry classroom. Responses from the questionnaire were coded 1-5 and the average for each question per country was used as an input for an MDS analysis of the teachers' understanding of inquiry. MDS provides a graphical interpretation of the similarity/dissimilarity between data. Countries with similar average responses are close together, while countries with differences in their average responses to this series of questions are further apart. The distribution of the responses based on each teacher cohort is mapped relative to an 'ideal' response (Figure 2). The 'ideal' response is this case 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 cluster into 3 broad groupings and one outlier. Nearest the 'ideal' are M and G – these were the 2 cohorts with a greater number of VE teachers and few BE teachers. Average responses for these cohorts tend towards the ideal, i.e. nearing agreement with the ideal response. Further from the ideal, the responses indicate more uncertainty with regards to their understanding. The cohorts furthest from ideal (A, B, D, H and the outlier E) include cohort B and E who had the greatest proportion of BE and no VE teachers.

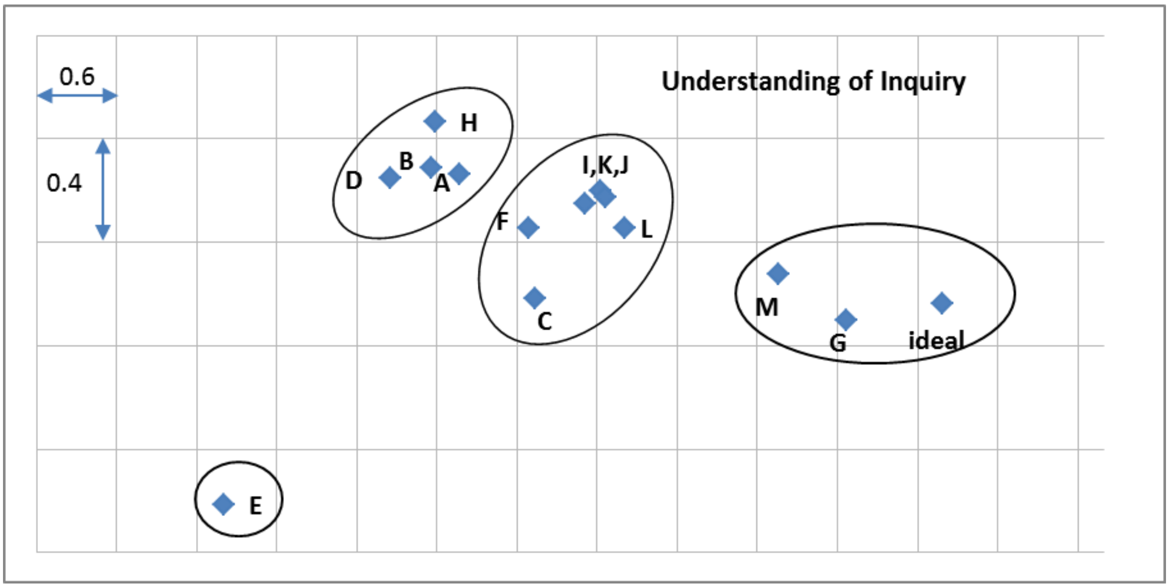


Figure 2: MDS diagram for Understanding of Inquiry, based on initial profile

Therefore much of the variation between teacher cohorts may be due to the difference in levels of experience of the individual teachers within each cohort. The responses to each question by the different experience level of the teachers is shown in Figure 3. These responses, based on their level of experience, clearly show a greater level of understanding of inquiry and the roles of teacher and student in an inquiry classroom, by the more experienced teachers (see Figure 3 and Table A1.1 in Appendix 1).

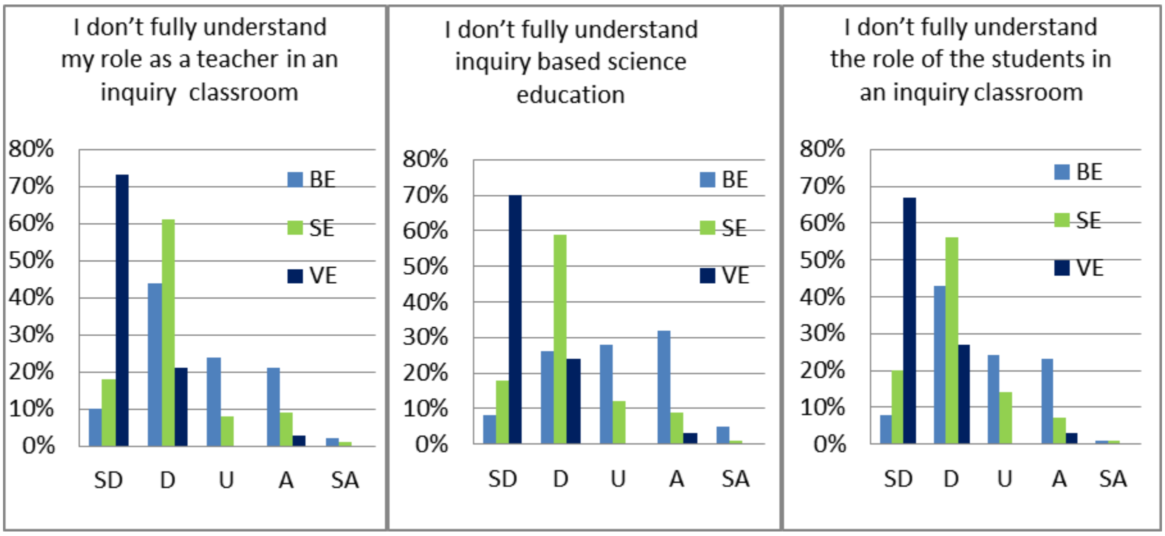


Figure 3: Responses to questions relating to Understanding of Inquiry, based on individual teacher experience in IBSE (SD, D, U, A, SA abbreviate for strongly disagree, disagree, uncertain, agree, strongly agree)

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.

Variations in responses to these questions are evident between teacher cohorts. 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 three clusters of teacher cohorts are evident. The group nearest the ideal (M, G, K) are those cohorts that have high proportions of VE teachers, in comparison to other cohorts. The difference between cluster 2 and cluster 3 lies principally in the response to whether inquiry takes up too much time, cluster 2 responses are uncertain, while cluster three responses disagree.

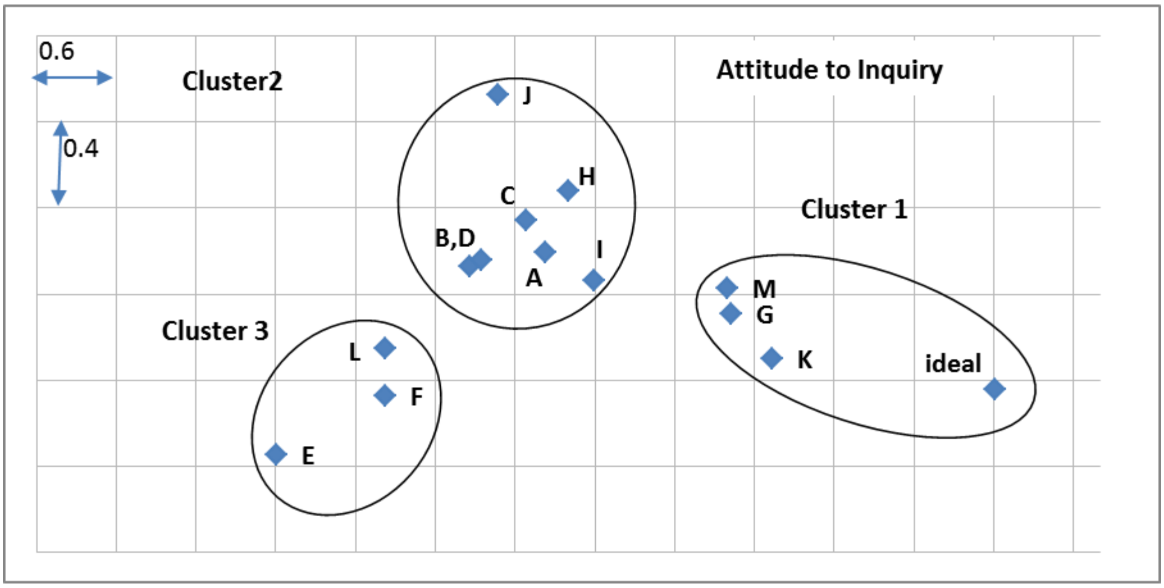


Figure 4: MDS diagram for Attitude to Inquiry, based on initial profile

Further analysing each statement based on teacher experience level shows variations (see Figure 5). Analysing the responses, based on level of experience, clearly shows a greater level of uncertainty in the BE grouping and increasing certainty for those with SE and VE for all three questions in this section (see Figure 5 and Table A1.2 in Appendix 1).

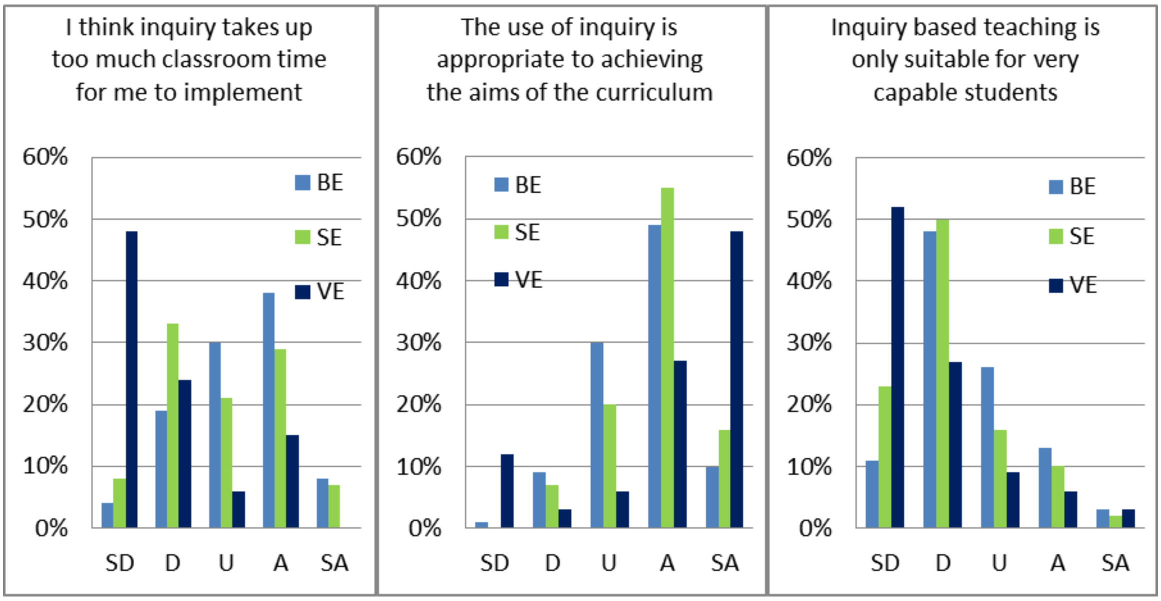


Figure 5: Responses to questions relating to Attitude to Inquiry, based on individual teacher experience in IBSE (SD, D, U, A, SA abbreviate for strongly disagree, disagree, uncertain, agree, strongly agree)

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 from industry into the classroom and to broaden the understanding 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;
- I often show students the relevance of science in industry;
- My 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 (Figure 6) shows a cluster of countries approximately equidistant from the ideal (I, A, C, K, L and M). Cluster analysis places D within cluster 2 with B as both cohorts agree more strongly that their students understand the importance of science and technology than the other cohorts.

The furthest group from the ideal (F, G, H and J) is generally more uncertain in their responses to this set of questions than teachers in other cohorts who tend to agree with most of the statements.

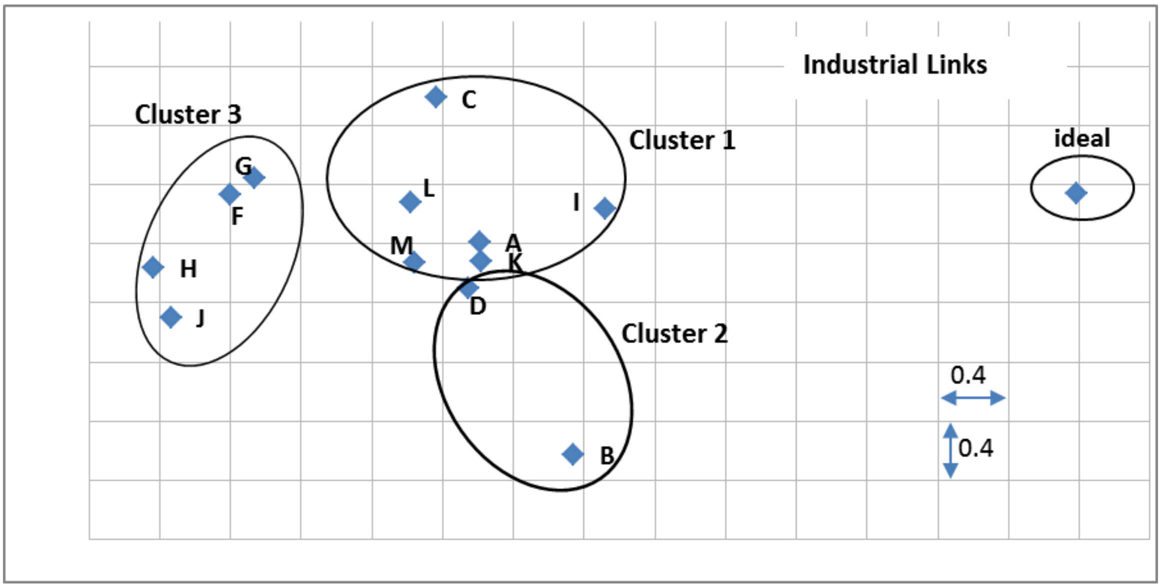


Figure 6: MDS diagram for Industrial Links, based on initial profile

Within this section, the variations between the teacher cohorts cannot be explained by proportions of BE and VE teachers. 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 80% of the BE teachers (and 94% of the VE teachers) stating that they want their 'students to know about the latest developments and applications of science and engineering' (Figure 7 and Table A1.3 in Appendix 1). The BE group indicate some difficulty in comparison to the VE group in relating 'scientific concepts in the curriculum to phenomena beyond the classroom' (Figure 7).

Figure 7: 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)

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. To determine if these practices occurred at all in the classroom, three statements were analysed; 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 disagreement with the first and second statement and strong agreement with the third. From MDS analysis, there are no cohorts of teachers who are close to the ideal (see Figure 8).

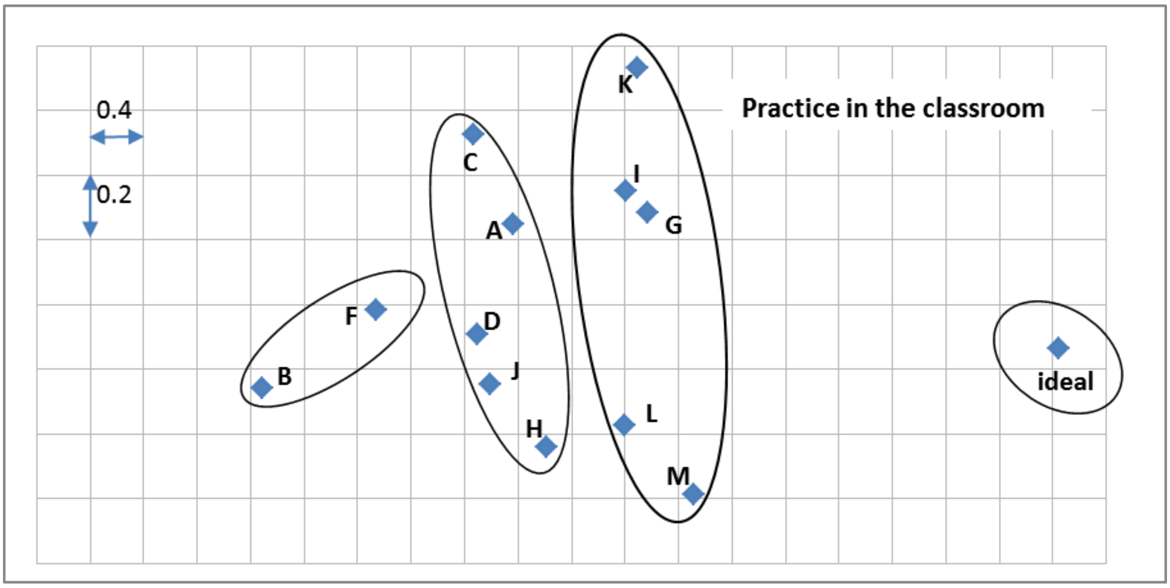


Figure 8: MDS diagram for Practice in the inquiry classroom, based on initial profile

The difference between all the cohorts and the ideal is strongly influenced by the response to the first statement. Within even the closest cluster to the ideal, only cohorts L and M disagree with this statement, while the others are uncertain. Cohorts B and F agree that they tell the students the right answer if an investigation leads to an unexpected result but are uncertain with regards to the other statements. This statement may be interpreted ambiguously as to the emphasis of the term 'always' and also as to when the teacher might tell the student the 'right answer', whether immediately, without allowing the student time to explore their reasoning and investigate their answer further or if the statement implies that the teacher would never inform the student of the right answer, allowing misconceptions to remain. At times, it can be necessary for teachers to tell students the correct result/answer, and it is unclear how teachers interpreted this question; in Figure. 9, for this statement the VE cohort are divided in their answer, 39% disagree, 27% uncertain and 30% agree with this statement.

Examining the responses on the basis of teacher experience level, there are large differences evident, with BE teachers more likely to 'tell the students the right answer/result' in an investigation and are more uncertain of how to ask 'higher order questions that promotes thinking'. Specifically, almost half of the BE group indicate that they are uncertain or do not have 'sufficient knowledge of science to implement an inquiry lesson effectively' (Figure 9 and Table A1.4 in Appendix 1).

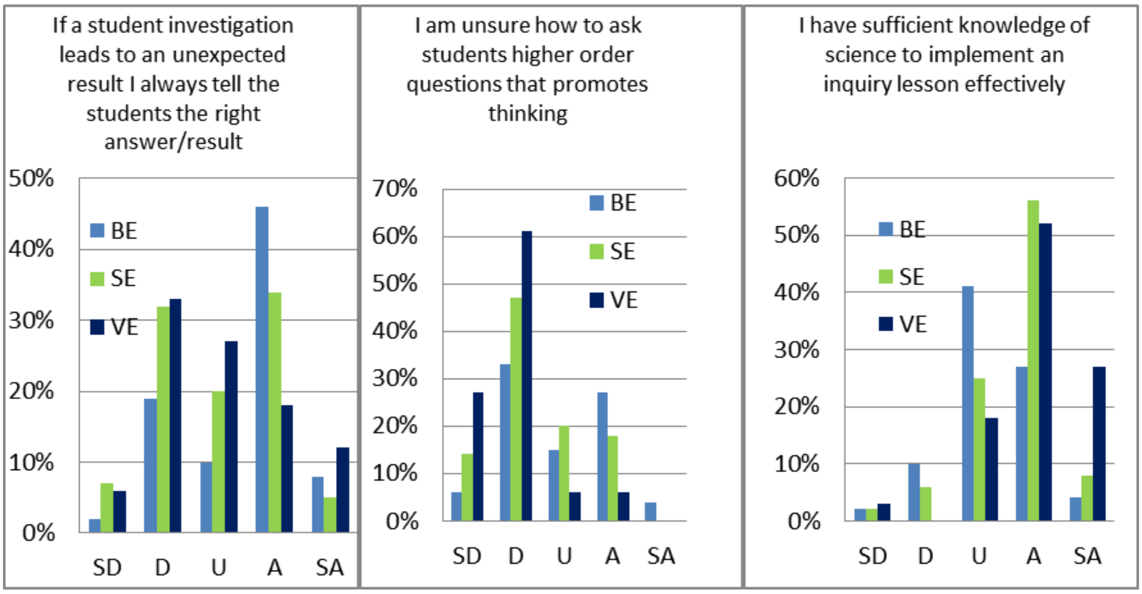


Figure 9: Responses to questions relating to Practice in the Inquiry Classroom, based on individual teacher experience in IBSE (SD, D, U, A, SA abbreviate for strongly disagree, disagree, uncertain, agree, strongly agree)

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 three loose cluster areas (Figure 10). Countries with more BE teachers tended to be further from the 'ideal' (C, F, and B).

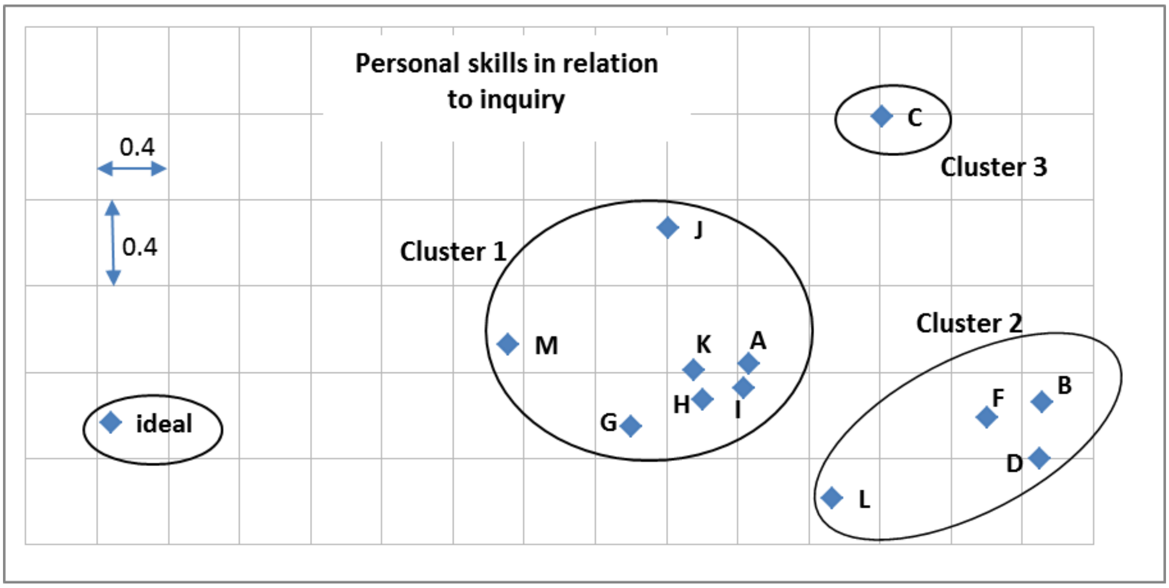


Figure 10: MDS diagram for Personal Skills in relation to inquiry, based on initial profile

The differences in location of the group B, F, D and L (cluster 2, Figure 10) with cohort C can be explained as follows: cohort C agree that it is difficult to manage a class where groups of students are doing different things, but are not uncomfortable if they are unable to answer students' questions or asking questions when they are uncertain of answers, while the cluster 2 group are more uncertain in their responses to these questions.

Analysis in further detail, based on the experience level of the teachers in each cohort, indicates that the VE group is closer to the 'ideal' response than BE or SE cohorts (Figure 11 and Table A1.5 in Appendix 1). While the responses of the VE group are closer to the ideal for each question, there are a significant proportion of responses furthest from ideal. E.g. 'Managing a classroom where each student group is doing different activities' is difficult for 24% of the VE group and up to 46% of the BE group. While many feel uncomfortable with teaching areas of science that they have limited knowledge of (45%VE and 60% BE), many are also 'uncomfortable with asking questions, in my class, where I am unsure of the answer myself' (34% BE and 21% VE). Self-perception as a teacher is also important but almost one-fifth of the group have feelings of inadequacy if they do not know answers to student questions (Figure 11 and in Table A1.5, Appendix 1).

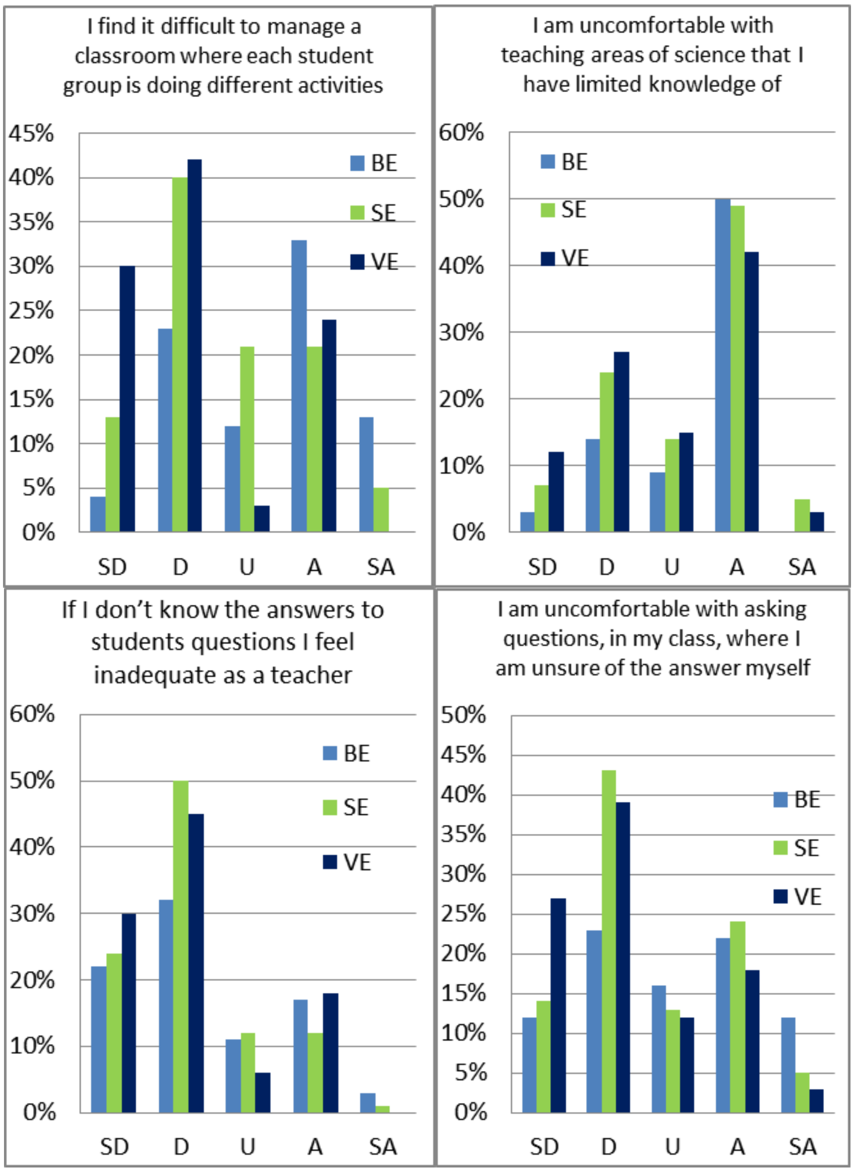


Figure 11: Responses to questions relating to Personal Skills in the Inquiry Classroom, based on individual teacher experience in IBSE (SD, D, U, A, SA abbreviate for strongly disagree, disagree, uncertain, agree, strongly agree)

1.2.6 Student/Teacher control

This section focussed on determining the extent of occurrence of implementation of particular practices within the classroom, which in turn was used to infer the extent of student involvement in inquiry activities and how much control students have within the inquiry activity.

These questions were from the PSI-T questionnaire (Campbell, Abd-Hamid, & Chapman, 2010) and are grouped into 5 sections, based loosely on the main activities involved in the inquiry process, namely: asking research questions, designing investigations, conducting investigations, collecting data and drawing conclusions. Responses from each question item were coded, particular groupings summed and then averaged as before. Eighteen out of twenty of the items in this section are coded positively with 1 representing "almost never" and 5 representing "almost always."

Asking Research Questions

In this group of statements *(items 47-50,* Appendix 4*)*, teachers were asked to indicate how often practices relating to the use of student questions occurred.

- Students formulate questions which can be answered by investigations;
- Student research questions are used to determine the direction and focus of the lab;
- Students framing their own research questions are important;
- Time is devoted to refining student questions so that they can be answered by investigations.

The 'ideal' response corresponds to teachers reporting that all of these practices occur almost always, i.e. that students have a lot of control in determining the research question that they wish to investigate. The mean response for this set of statements is 2.9, implying that students sometimes determine the research question being investigated. MDS analysis (Figure 12) identifies four cluster groups. The cluster containing K and C agree that students formulate questions which can be answered by investigations, while other cohorts are uncertain, and K and C are also more positive/less uncertain in the responses to the other questions than any of the other cohorts. Cohort E disagrees more than others with the statement that 'students framing their own research questions are important'.

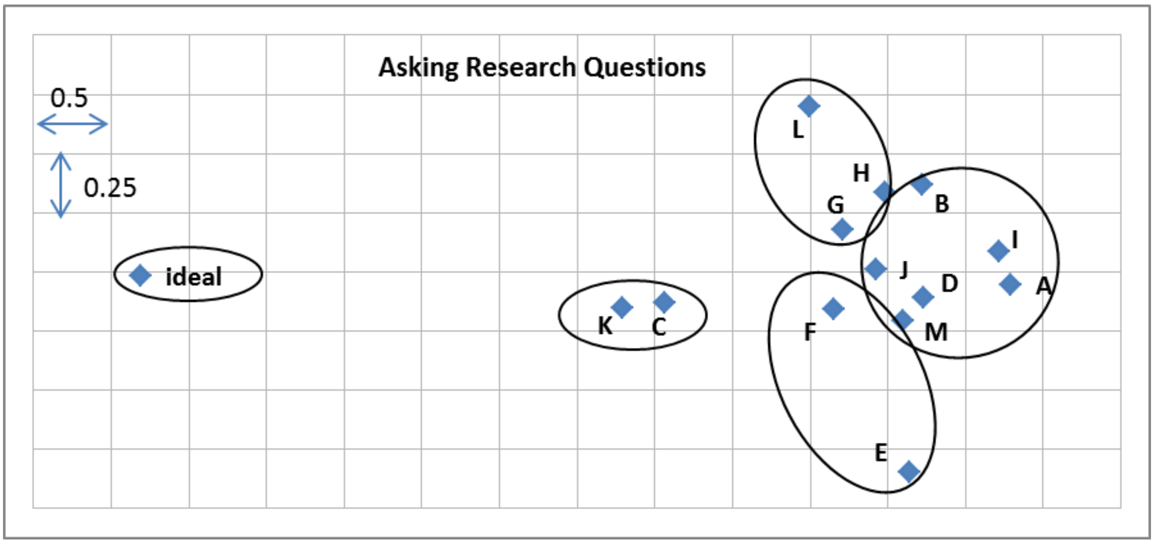


Figure 12: MDS diagram for frequency of students Asking Research Questions based on initial profile

There are statistically significant changes in the mean (based on Wilcoxan Signed Rank Test) depending on the experience level of teachers. The frequency of activities based on teacher experience is shown in Figure 13 (and in Table A1.6 in Appendix 1). For the very experienced cohort, 51% of teachers report that their students often or almost always formulate questions that can be answered by investigations in comparison to 24% of SE teachers and 31% of BE teachers. 42% of VE teachers allow their students questions to determine the focus of the lab in comparison to 16% of SE teachers and 19% of BE teachers. 42% of VE teachers often or almost always take time to refine students questions in comparison to 23% of SE teachers and 19% of BE teachers. Significant differences in responses are also apparent between VE and SE cohorts in terms of the frequency of the importance of students framing their own questions.

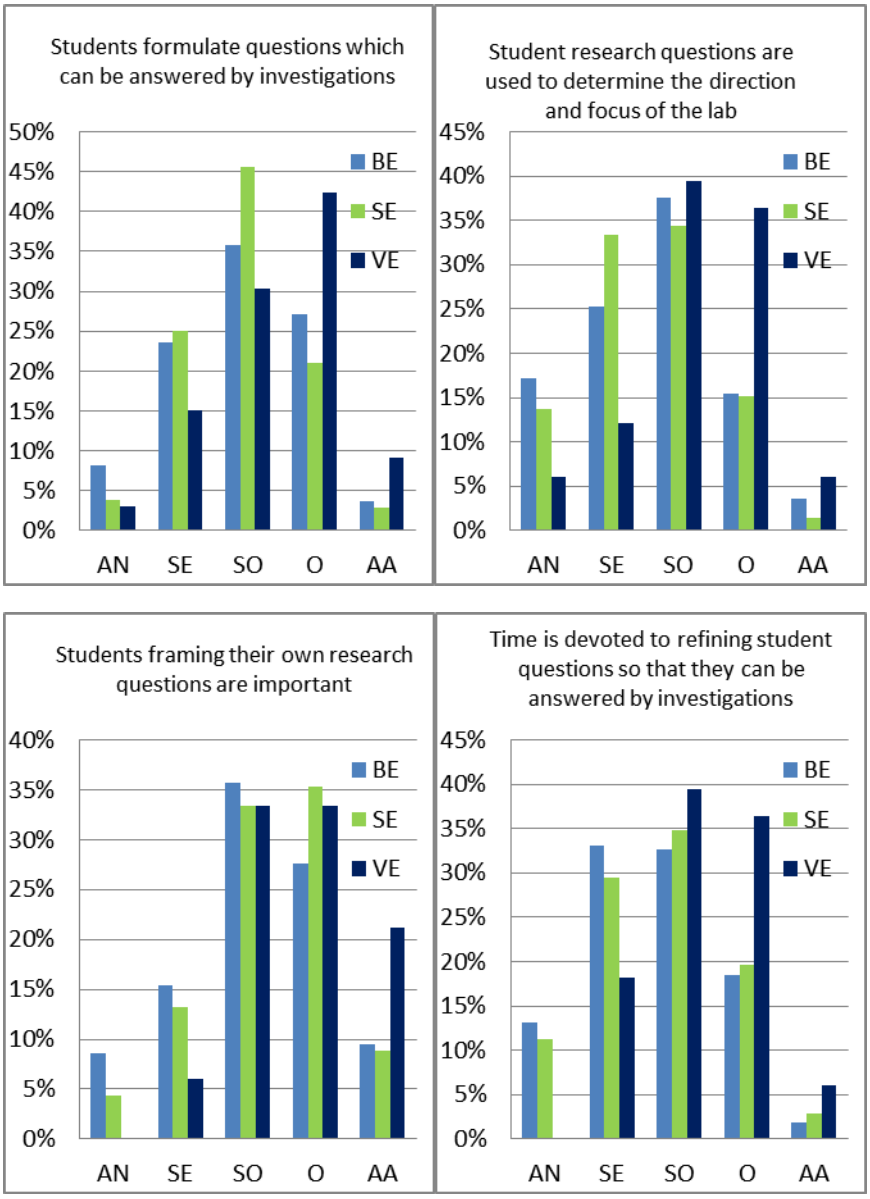


Figure 13: Responses to questions relating to Asking Research Questions, based on individual teacher experience in IBSE (AN, SE, SO, O, AA abbreviate for almost never, seldom, sometimes, often, almost always)

Designing Investigations

This group of statements *(items 51-54,* Appendix 4*)* define how often teachers allow their students to design, critique and justify their own investigation procedures, namely:

- Students are given step-by-step instructions before they conduct investigations;
- Students design their own procedures for investigations;
- Students engage in the critical assessment of the procedures that are employed when they conduct investigations;
- Students justify the appropriateness of the procedures that are employed when they conduct investigations.

The 'ideal' case is represented by agreement that students 'almost always' design their own procedures, engage in critical assessment and justify the appropriateness of procedures, while students are rarely given step-by-step procedures. The average response for this series of questions is 2.88 implying that these practices occur 'sometimes'.

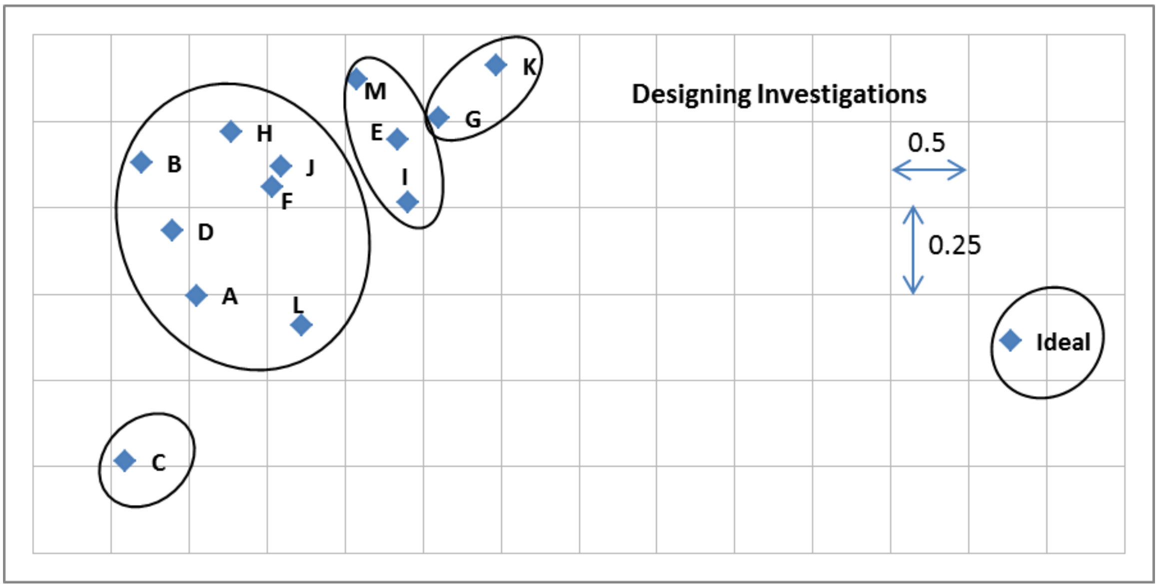


Figure 14: MDS diagram for frequency of students Designing Investigations based on initial profile

MDS analysis identifies four clusters (Figure 14). The cluster with cohorts M, E and I responded that their students sometimes are given step-by-step instructions, sometimes design their own investigations, engage in the critical assessment and justify appropriateness of the procedure employed. Cohort C often provides students with step-by-step instructions, students seldom determine their own procedures and engage in critical assessment of procedures, but sometimes justify the appropriateness of procedures.

Responses to the statements strongly depend on the experience level of teachers with significant differences in mean response based on Mann-Whitney Analysis. BE teachers more frequently give students step-by-step instructions with 64% reporting that they often or almost always do so in comparison to 27% of the VE group. 51% of VE teachers report that their students often or almost always critically evaluate the procedures employed in an investigation in comparison to 39% of SE teachers and 17% of BE teachers. Figure 15 (and Table A1.7 in Appendix 1) shows how often teachers allow their students to design, critique and justify their own investigation procedures by teacher experience level.

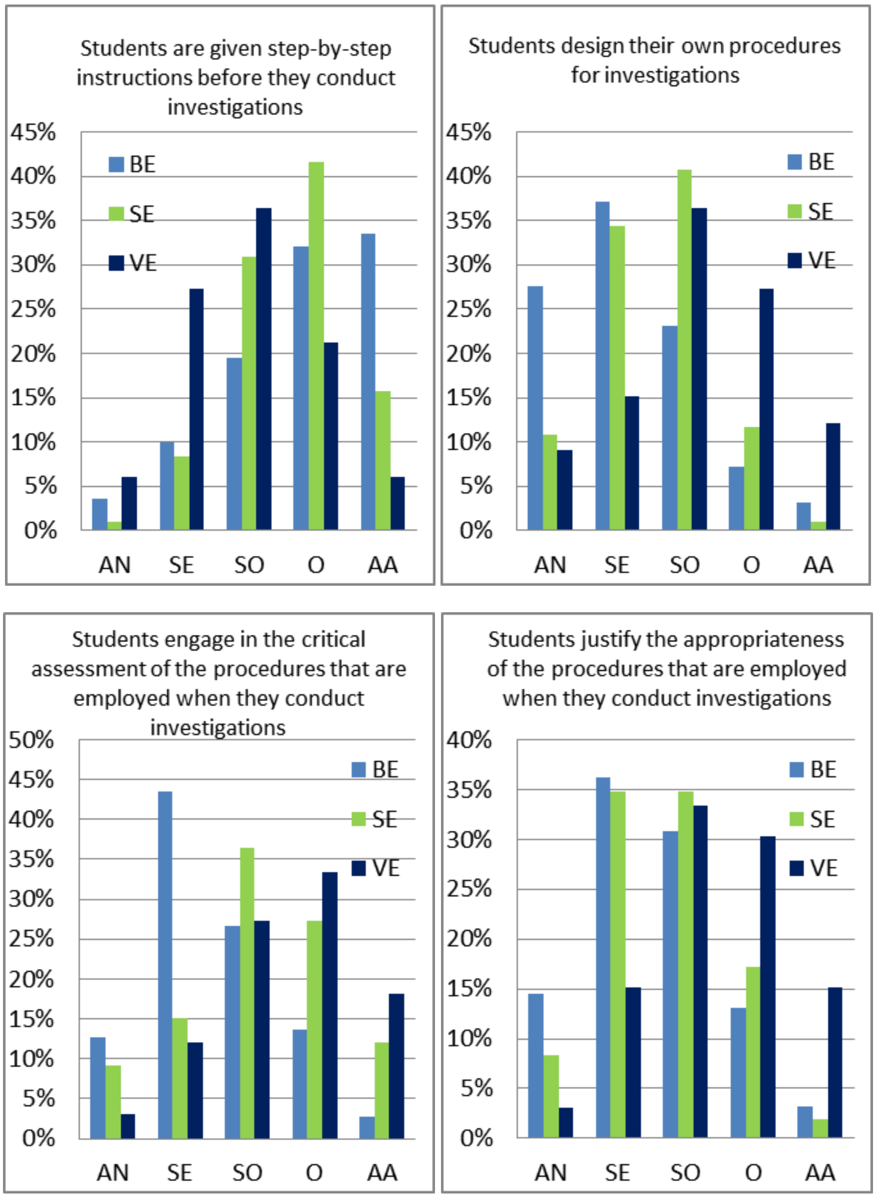


Figure 15: Responses to questions relating to Designing Investigations, based on individual teacher experience in IBSE (AN, SE, SO, O, AA abbreviate for almost never, seldom, sometimes, often, almost always)

Conducting Investigations

This group of statements *(items 55-58,* Appendix 4*)* determine how often students participate in the conduction of their own investigations, as follows:

- Students conduct their own procedures of an investigation;
- The investigation is conducted by the teacher in front of the class;
- Students actively participate in investigations as they are conducted;
- Each student has a role as investigations are conducted.

Responses were rated from 1 to 5, with 5 representing student participation ‘almost always’. (Note that the second statement was coded in reverse). The mean of the overall group was 3.22 suggesting that teachers at least ‘sometimes’ allow these practices to occur in their classrooms. Three separate clusters were identified by MDS analysis (Figure 16).

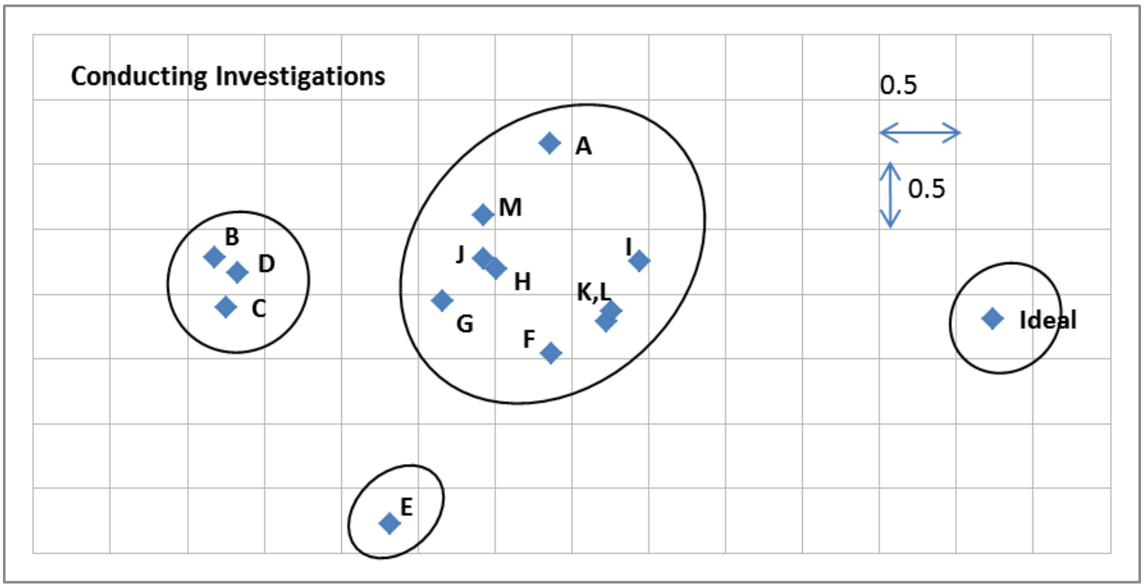


Figure 16: MDS diagram for frequency of students Conducting Investigations based on initial profile

Figure 17 (and Table A1.8 in Appendix 1) shows how often students conduct their own investigations based on teacher experience level. With increased teacher experience, students more frequently conduct their own investigations, actively participate in investigations and have their own role in an investigation and teacher demonstrations occur less frequently.

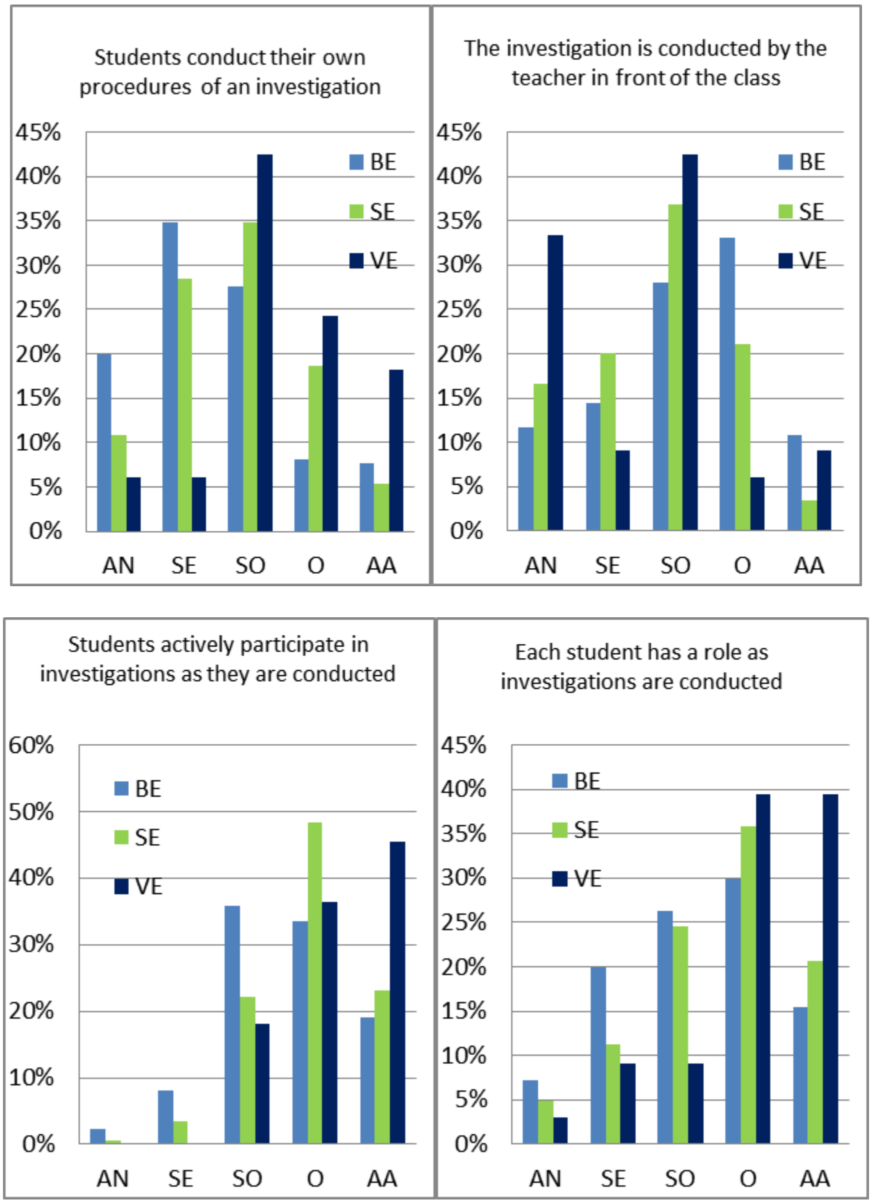


Figure 17: Responses to questions relating to Conducting Investigations, based on individual teacher experience in IBSE (AN, SE, SO, O, AA abbreviate for almost never, seldom, sometimes, often, almost always)

Collecting Data

When conducting investigations, a key learning opportunity for students is to decide on what data should be collected, why it needs to be collected and how it should be collected. This group of statements *(items 59-62,* Appendix 4*)* determines the frequency that students are allowed to make these decisions. Responses were rated from 1 to 5, with 5 indicating that students have control of these decisions 'almost always'. The mean value obtained is 3.04 suggesting that students are given this control 'sometimes' within the classroom, namely:

- Students determine which data to collect;
- Students take detailed notes during each investigation along with other data they collect;
- Students understand why the data they are collecting is important;
- Students decide when data should be collected in an investigation.

Looking at the MDS (Figure 18), the group closest to the ideal, containing cohorts K, I, G, L and D, responded that students sometimes determined which data to collect and sometimes or often took detailed notes along with data and understood why the data they are collecting is important. The further away from the ideal, the less frequently these practices occurred and for cohort E all of these practices seldom occurred.

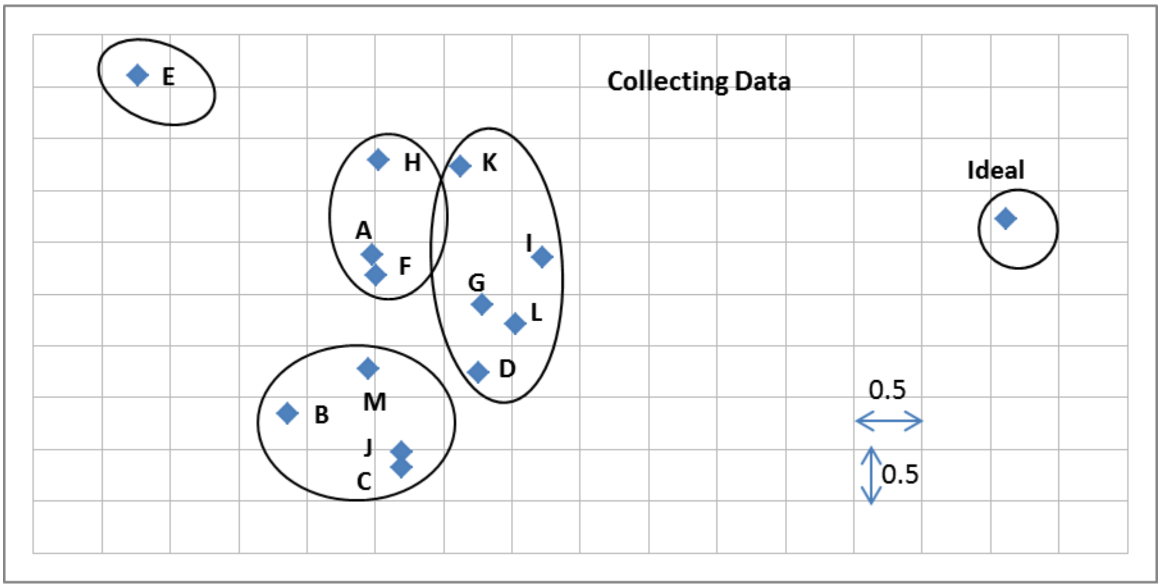


Figure 18: MDS diagram for frequency of students Collecting Data based on initial profile

Figure 19 (and Table A1.9 in Appendix 1) shows the frequency of student control with data collection. The students of the VE group of teachers appear to be more often directly involved in data collection practices than those students of the BE or SE teacher. This applies for determining what data to collect, why they collect it and when to collect it. Taking detailed notes during an investigation is a practice encouraged by most of the teachers.

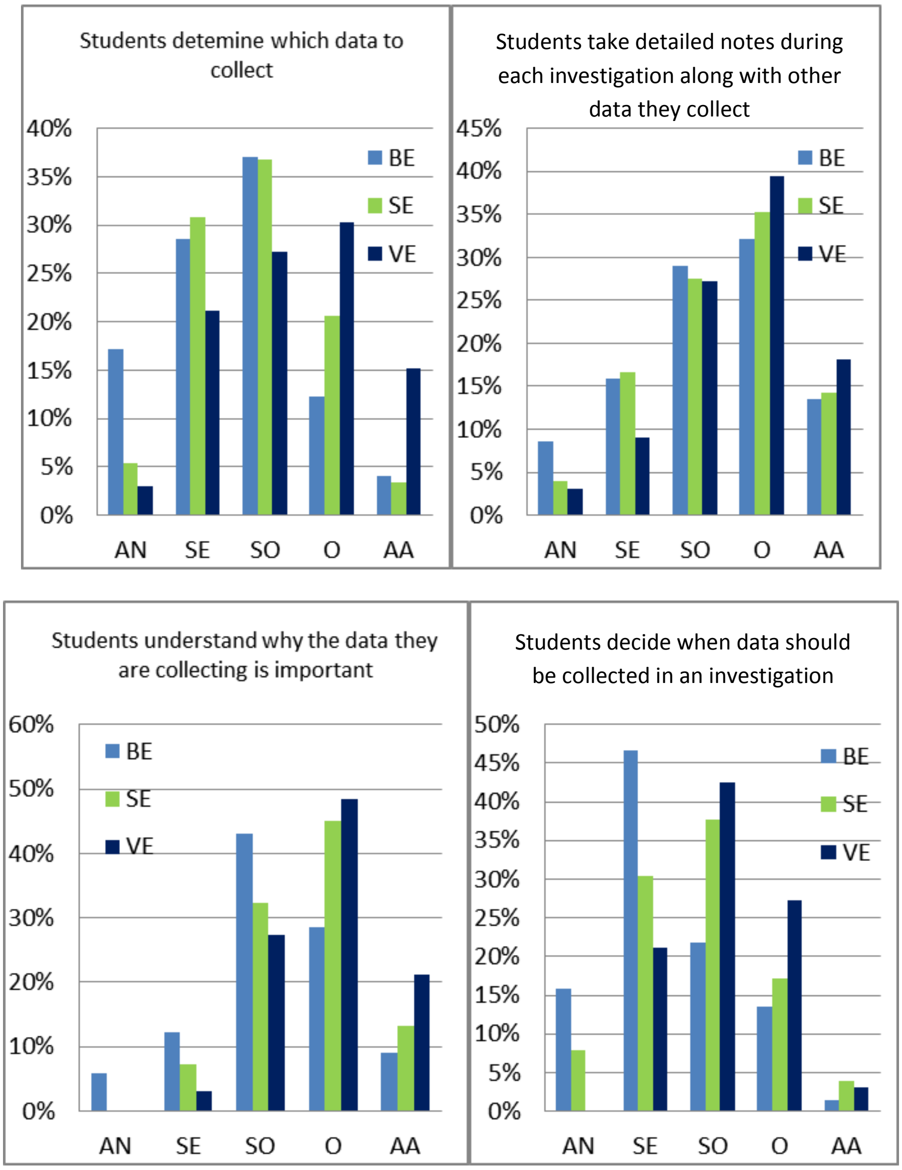


Figure 19: Responses to questions relating to Collecting Data, based on individual teacher experience in IBSE (AN, SE, SO, O, AA abbreviate for almost never, seldom, sometimes, often, almost always)

Drawing Conclusions

Within this group of statements *(items 63-66,* Appendix 4*),* teachers were asked to indicate how often their students draw conclusions, interpret evidence, use scientific knowledge and justify conclusions, by themselves, after conducting investigations. Responses were rated from 1-5, with 5 suggesting that the teachers stated that their students are involved in these activities 'almost always.' The mean score was 3.22, which suggests that these practices occur 'sometimes' to 'often' within their classrooms:

- Students develop their own conclusions for investigations;
- Students consider a variety of ways of interpreting evidence when making conclusions;
- Students connect conclusions to scientific knowledge;
- Students justify their conclusions.

MDS analysis (Figure 20) identifies four clusters.

The cluster containing I, Land K is closest to the ideal. For this cluster, responses showed that students often develop their own conclusions for investigations, connect their conclusions to scientific knowledge and justify their conclusions. Cohort C responded that their students sometimes engaged in these practices but seldom consider a variety of ways of interpreting evidence when making conclusions.

Figure 21 (and Table A1.10 in Appendix 1) shows the frequency for students drawing conclusions based on teacher IBSE experience level. There are significant differences in mean response based on Mann Whitney tests. As teacher experience level increases, a greater percentage of teachers report that their students frequently develop their own conclusions, interpret evidence in a variety of ways, connect conclusions to their scientific knowledge and justify their conclusions.

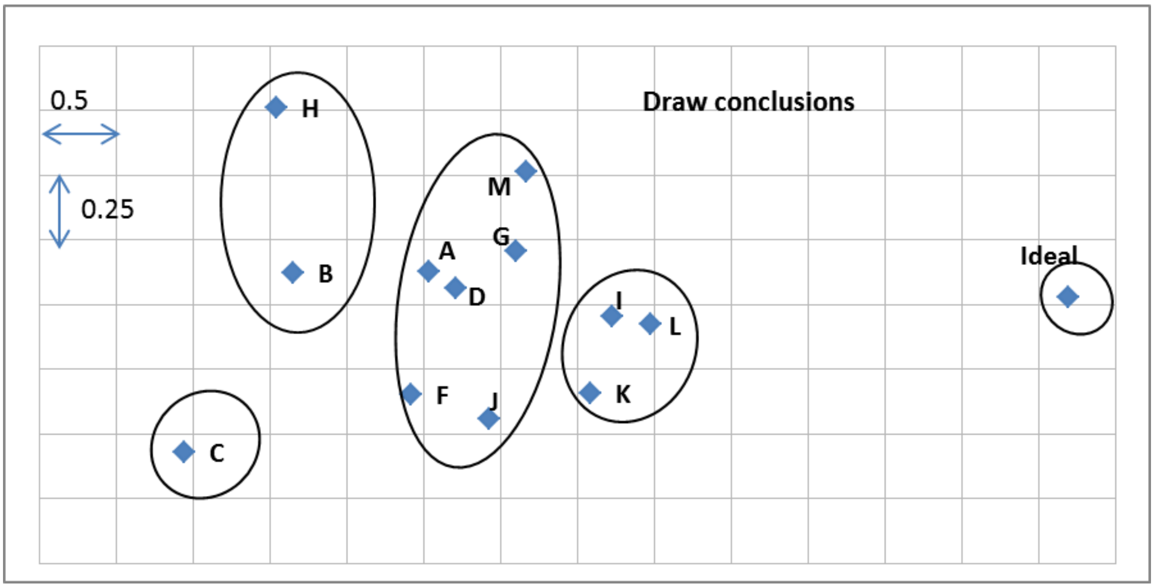


Figure 20: MDS diagram for frequency of students Drawing Conclusions based on initial profile

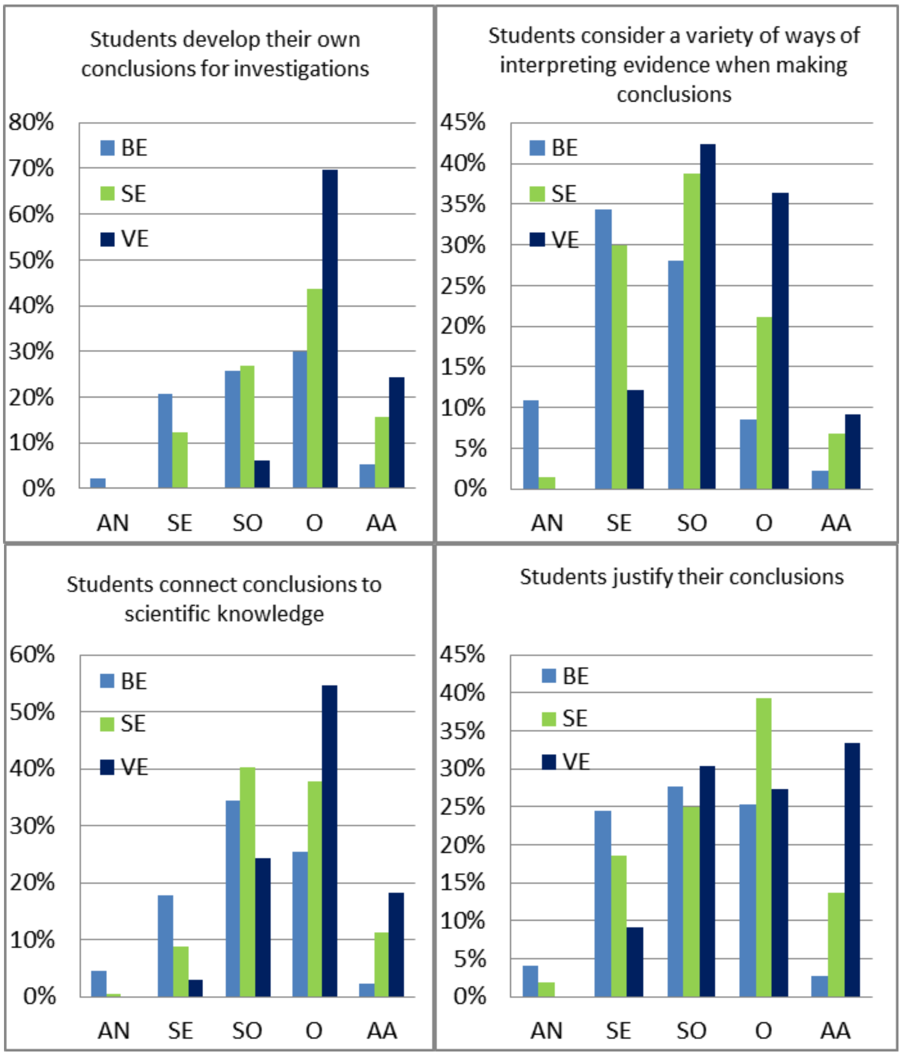


Figure 21: Responses to questions relating to Drawing Conclusions, based on individual teacher experience in IBSE (AN, SE, SO, O, AA abbreviate for almost never, seldom, sometimes, often, almost always)

1.3 Conclusion

Teachers' understanding of inquiry was strongly influenced by the experience level of teachers, with cohorts containing a large proportion of SE and VE teachers fully understanding inquiry and the role of teachers and students in an inquiry classroom. In terms of reported barriers to implementing inquiry such as time-pressures and lack of suitability for all student abilities, BE cohorts were more uncertain towards overcoming these barriers while experienced teachers felt that these issues were not so important. With regard to industrial links, teachers value a broader view of science in the classroom, with over 80% of the BE teachers (and 94% of the VE teachers) stating that they want their 'students to know about the latest developments and applications of science and engineering'.

There are large differences seen with classroom practice; BE teachers are more likely to 'tell the students the right answer/result' in an investigation and are more uncertain of how to ask 'higher order questions that promotes thinking'. Managing a classroom where each student group is doing different activities is difficult for 24% of the VE group and up to 46% of the BE group. While many feel uncomfortable with teaching areas of science that they have limited knowledge of (45%VE and 60% BE), many are also 'uncomfortable with asking questions, in my class, where I am unsure of the answer myself' (34% BE and 21% VE). Self-perception as a teacher is also important but almost one-fifth of the group with feelings of inadequacy if they do not know answers to student questions.

In terms of student control in an inquiry classroom, the average response implies that students sometimes determine the research question, design investigations, conduct investigations, decide which data to collect and draw conclusions. This may suggest that the type of inquiry used tends to be more 'guided' than 'open.

SECTION 2 Change in profile after Teacher Education Programme

In this section, the change in the teacher profile after teachers attended the TEP 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, who completed both the initial and final questionnaires, is noted in Table 1. The change in profile, as determined from MDS analysis, is shown under each attribute heading per teacher 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, at the beginning of teacher education programme, to the final questionnaire, completed after the programme. 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 teacher education programme is shown in Figure 22.

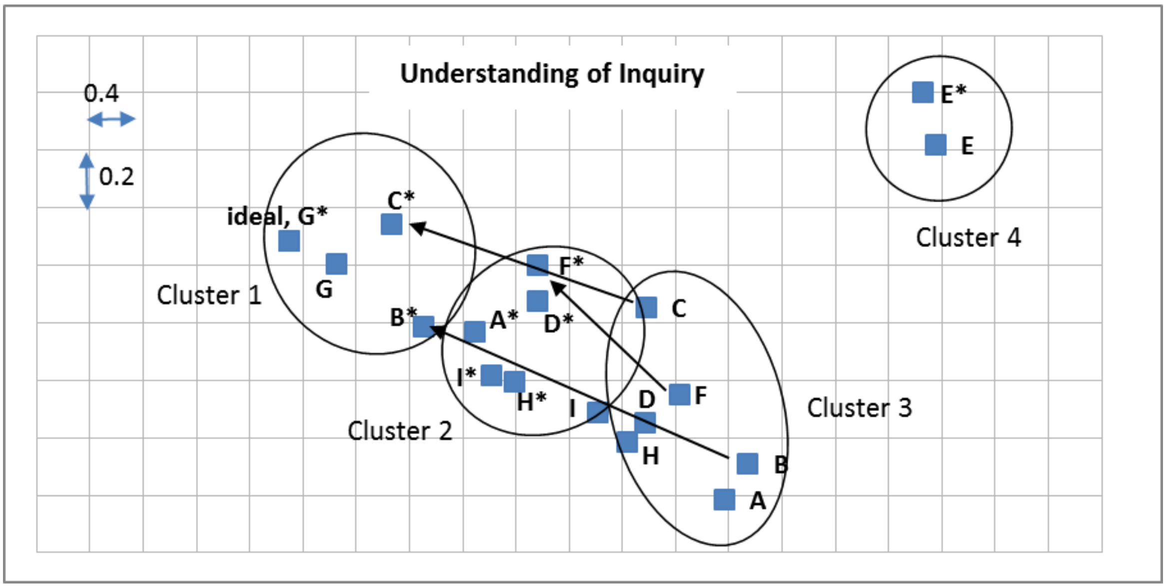


Figure 22: MDS of Understanding of Inquiry, based on matched pairs, per cohort (* denotes responses after teacher education programme)

Four distinct clusters can be seen in the MDS (Figure 22); cluster 3 depicts responses that are uncertain or disagree with the three statements in the questionnaire (see Section 1.2.1); cluster 2 depicts responses in the disagree category (closer to the ideal); while cluster 1 is very close to ideal response, strongly disagreeing with all statements. One cohort (E) is furthest from the cluster as they indicate that they do not understand inquiry, and while they do understand the role of the teacher, they are uncertain as to the role of the student in the inquiry classroom.

In all cases, the averaged response from each cohort has shifted closer to the ideal, after the teacher education programme, with the exception of cohort E.
Large shifts after the teacher education programme are evident in most cohorts but particularly A, B, C, D and F. The G cohort is near the ideal initially and remains there after the TEP. As a total cohort, the teachers have shifted towards a greater understanding of inquiry and also an increased understanding of the roles of teacher and student in the inquiry classroom.

Component Questions

From averaged responses to each of the individual questions, there are statistically significant changes in the mean (based on Wilcoxan 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 cohorts A, B, C and I;
- increased understanding of role of teacher in the inquiry classroom - by cohorts A, B, C, D and F;
- increased understanding of role of student in the inquiry classroom - by cohorts B, C and F.

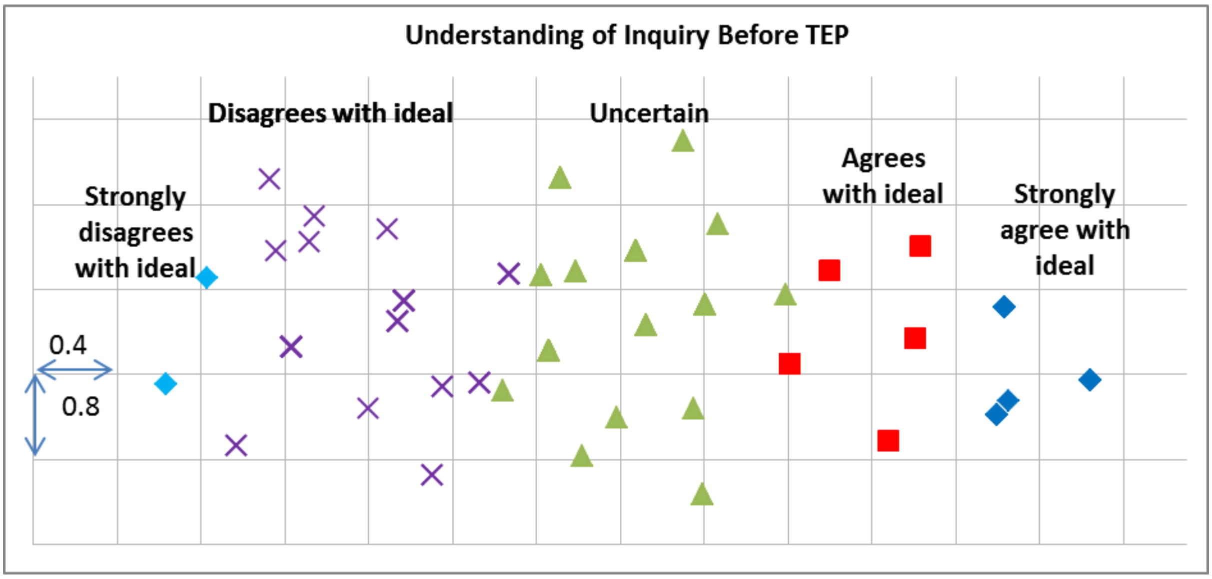
So there is clear indication that workshops have increased participants understanding of inquiry and the role of the teacher and of the student in the inquiry classroom.

Teacher Experience Level

Statistical differences are evident in the changes of the mean scores of the BE cohort and SE cohort of teachers (see 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 amounts to 162 teachers. The MDS plot of their profile at the beginning and after TEP is shown in Figure 23. 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 on Figure 23, clusters could be made showing that 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 24 shows the number of teachers within each category in both the initial and final surveys. Clearly, there is a large shift towards the ideal by the BE group of teachers. A similar trend can be seen with the SE group of teachers, but the change is not as marked as the cohort is closer to the ideal anyway (see Figure A2.1, Appendix 2).

Key conclusion

Almost all cohorts have increased their understanding of inquiry and their understanding of the roles of teacher and student in an inquiry classroom, after attending the teacher education programme. The bigger shift in understanding has been in those who classify themselves as beginners in IBSE.



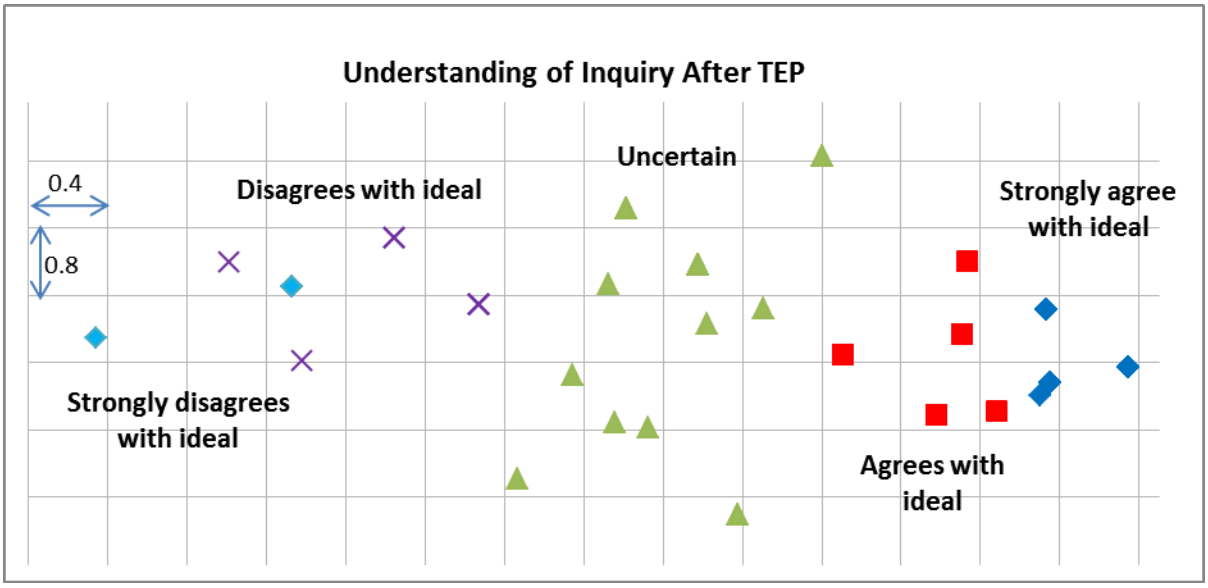


Figure 23: MDS of BE group Understanding of Inquiry, before and after the teacher education programme

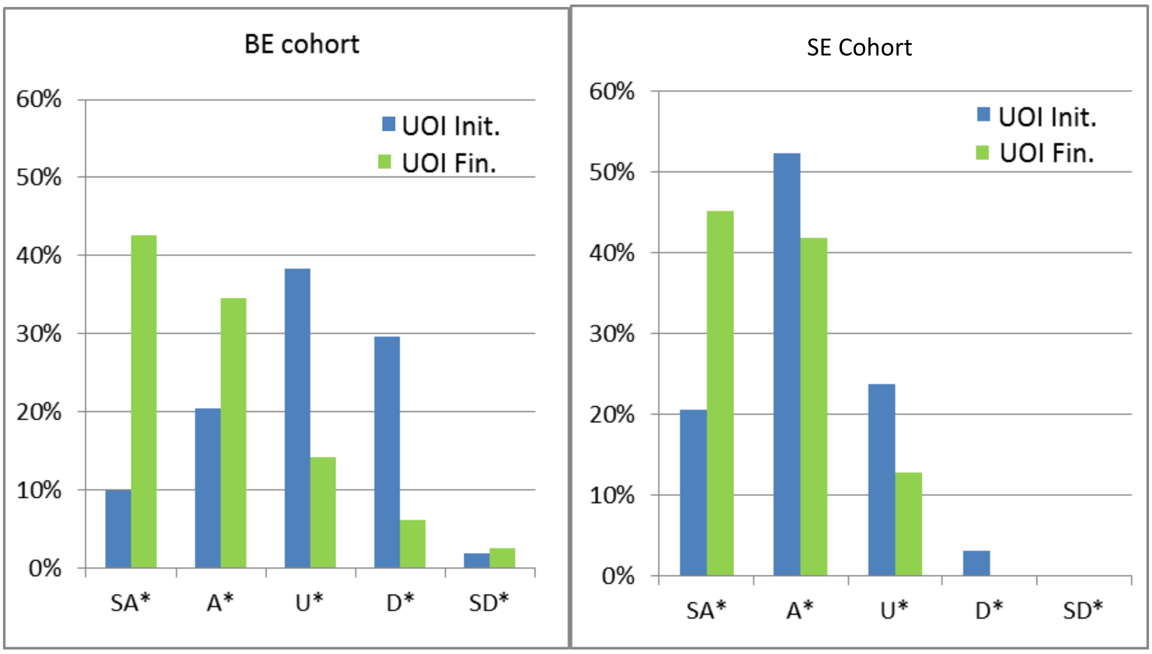


Figure 24: Proportion of teachers within cluster groups initially and finally (a) BE cohort, (b) SE cohort (UOI Init = Understanding of Inquiry from initial questionnaire, UOI Fin = Understanding of Inquiry from final questionnaire) (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

2.2 Attitude to inquiry

Overview

Responses to attitudes to inquiry by matched pairs of teacher cohorts were analysed by MDS and plotted in Figure 25. The questions used are:

- 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.

Three clusters are evident on the MDS plot (Figure 25). The responses to the questions associated with cluster 2 are more 'uncertain' while those in cluster 1 are tending more towards the ideal response.

The change in responses by each cohort after the teacher education programme is shown in Figure 25. While no cohort was at the ideal, there was a shift towards the ideal evident in cohorts A, B, C, and to a smaller extent, H and I. Two cohorts (E and F) are external to cluster 1 and 2 initially, due mainly to stronger agreement that 'inquiry takes up too classroom time to implement' and 'uncertainty that inquiry is only suitable for the very capable students'. Cohort E agree more strongly after the workshops that 'inquiry takes up too classroom time to implement'.

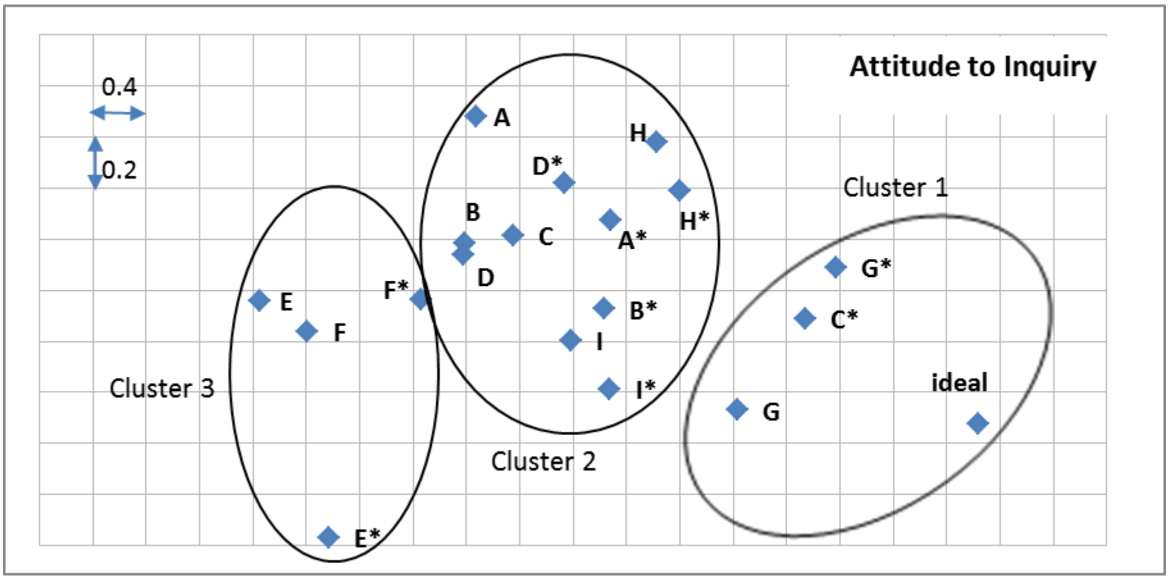


Figure 25: MDS of Attitude to Inquiry, based on matched pairs, per country (* denotes responses after teacher education programme)

Component Questions

Statistically significant changes (p<0.05) in the mean responses to individual questions before and after the teacher education programme (see Table A2.2 in Appendix 2), 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 - shifts by cohorts B and C from uncertain to disagree;
- Use of inquiry is appropriate to achieving the aims of the curriculum - shifts by cohorts B, C and E from uncertain to positive agreement;
- Inquiry based teaching is only suitable for the very capable students – shift from uncertain to disagree by cohorts A, B, E and F while cohorts C and D shifted towards stronger disagreement.

Together this data suggests that the attitude of the teachers has changed after the teacher education programme to address some of the obstacles usually put forward for not engaging with inquiry activities.

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 and VE groups (see Table A2.2 in Appendix 2). Therefore the changes in responses of the BE and SE cohorts were considered separately. 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 (Figure A2.2 in Appendix 2) and the number of teachers within each category was compared, before and after the teacher education programme. The percentage of teachers in each of the categories both before and after the teacher education programme is shown in Figure 26, for both the BE cohort and the SE cohort.

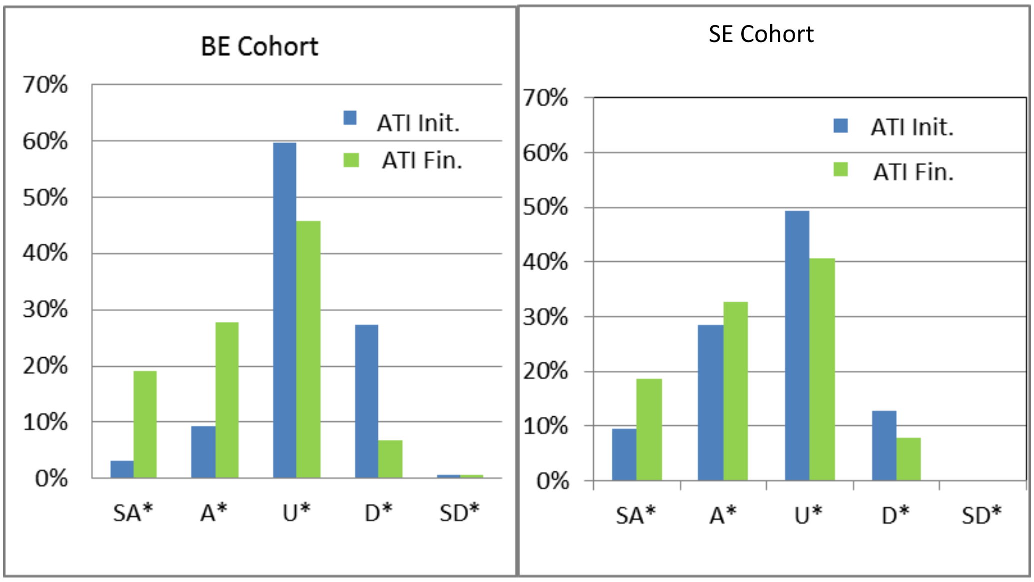


Figure 26: Numbers of teachers in each category, before and after the teacher education programme for BE and SE cohorts (AT1 attitude to Inquiry; Init, Fin are Initial and final questionaires) (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

Key conclusion

From this data, it is clear that the attitudes to inquiry have shifted after the teacher education programme towards the ideal response by the majority of the teacher cohorts and particularly, the effect seems to be more significant on the BE cohort.

2.3 Industrial Links

Overview

All data relating to responses for statements relating to industrial links, before and after the TEP, have been analysed by MDS. Statement analysed in this section were:

- 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;
- I often show students the relevance of science in industry;
- My 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.

MDS analysis data is plotted in Figure 27. Two cohorts do not shift significantly after TEP, namely cohorts G and H. Cohort F remains outside the main cluster but does shift slightly closer to the cluster and the ideal. There is again convergence after the TEP with B and C moving into the cluster. Cohort C, after the TEP, agree that they can 'easily relate scientific concepts in the curriculum to phenomena beyond the classroom' and that their 'students understand the importance of science and technology for our society'. This is in contrast to cohort B, who after the TEP, are more uncertain to 'often show students the relevance of science in industry' and have students who 'understand the importance of science and technology for our society'.

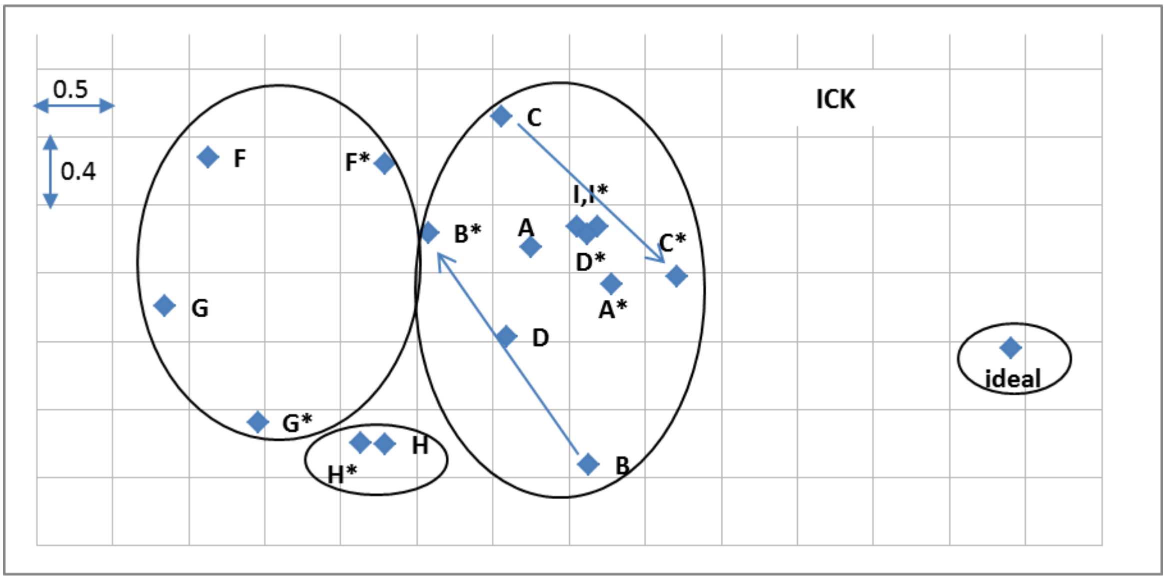


Figure 27: MDS diagram for Change in Industrial Links as shown by matched pairs, per country (* denotes responses after teacher education programme)

Component Questions

Few statistically significant ($p<0.05$) questions contribute to this section. Responses differed significantly for the following statements after the TEP:

- I want my students to know about the latest developments and applications of science and engineering – cohort C shift to more strong agreement;
- I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom – cohort C shift to more strong agreement;

- I often show students the relevance of science in industry – shift from uncertain to agree by cohort F; shift by cohort C to less strongly agree with this statement;
- My students understand the importance of science and technology for our society – Cohort C shift from uncertain to agree, but cohort B shifts from strongly agree to agree while cohort D shifts to slightly less agreement;
- If I had more information about industrial processes, I would use it in my teaching – cohort C agree more strongly.

This data is summarised in Table A2.3 in Appendix 2.

Teacher Experience Level

The shift in individual teachers is analysed based on their experience level with IBSE, as outlined earlier. MDS data is shown in Figure A2.3 in Appendix 2 for both the BE and SE cohorts and the output is summarised in Figure 28. Both before and after the TEP, there is a similar pattern to the BE and SE cohorts in terms of their answers to questions relating to Industrial Links. From Figure 28, examining the shift in the BE cohort, there is a small move of about 10 % of the teachers moving towards the ideal but changes are not as significant here as in other areas. This shift in awareness towards the ideal is by both cohorts.

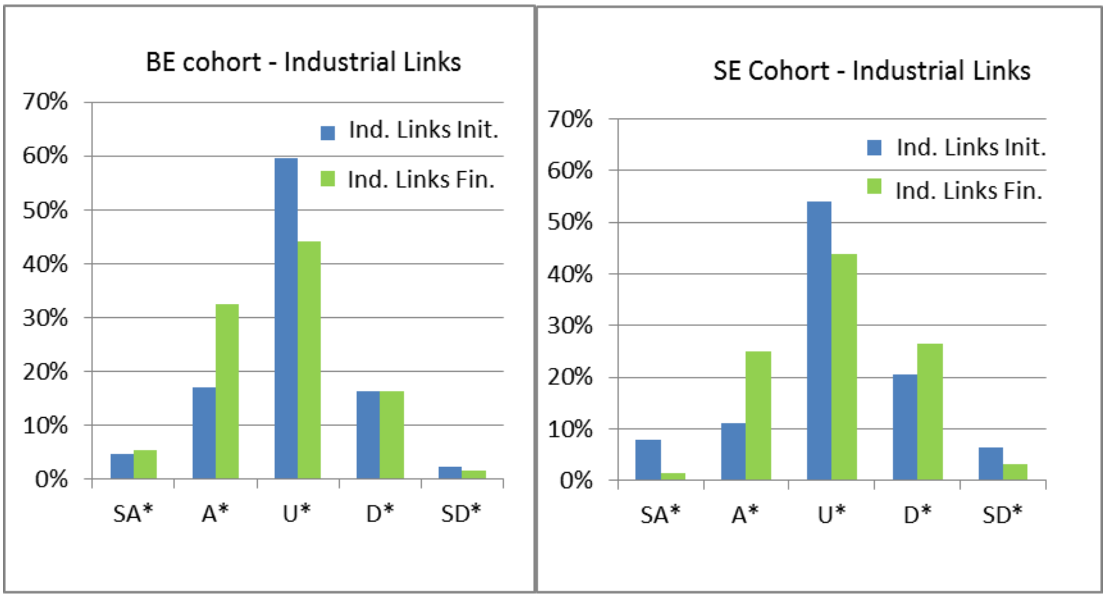


Figure 28: Numbers of teachers in each category, before and after TEP for BE and SE cohorts (Industrial Links) (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

Key conclusion

While small shifts were evident by most of the teacher cohorts after the TEP, these changes occurred for both teachers who were beginners in inquiry and those with some experience.

2.4 Practice in the inquiry classroom

Overview

Responses to three questions relating to specific aspects of inquiry teaching, before and after the TEP, was analysed by MDS:

- 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.

The cohorts fall into 2 clusters initially (Figure 29). Cohorts B and F are further from the ideal as they disagree with the statement ‘If a student investigation leads to an unexpected result I always tell the students the right answer/result’, while the cohorts in the main cluster agree with this statement.

After the TEP, there are several small shifts by cohorts B, I, A and G. However, there is a large shift in cohort H away from the ideal response - due mainly to a shift from ‘feeling confident about asking higher order questions’ to ‘feeling that they do not have the ability to ask higher order questions’. This cohort also shifted from agreeing that they had sufficient knowledge of science to implement an inquiry lesson effectively to disagreeing with this statement. The shifts evident in cohort C are largely due to stronger disagreement that they would always tell the student the correct answer if a student investigation lead to an unexpected result, and also a shift from uncertain to disagree that they had sufficient knowledge of science to implement an inquiry lesson effectively.

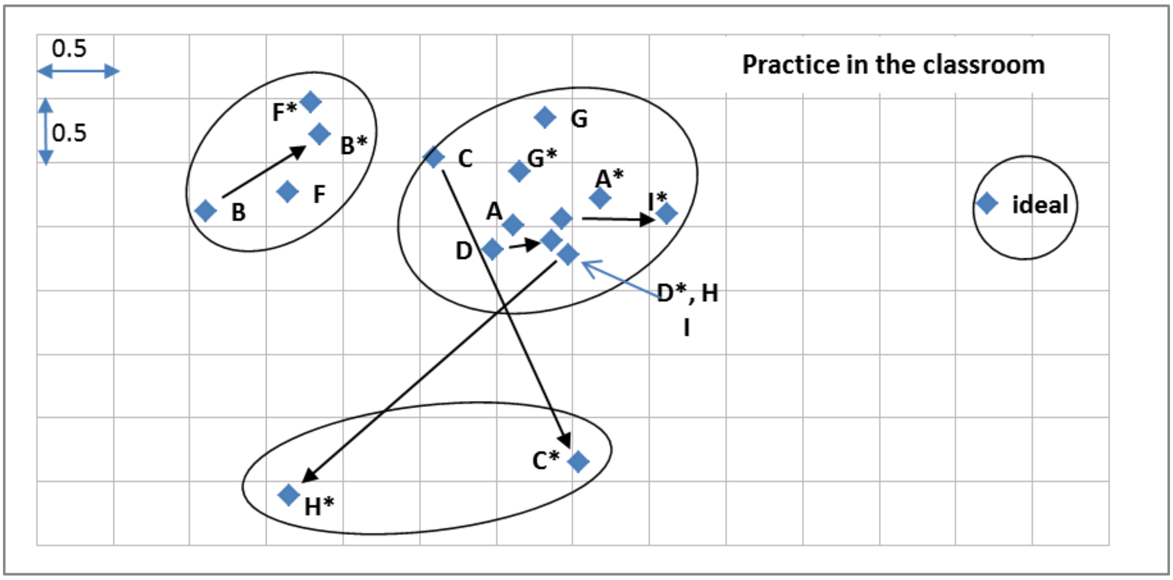


Figure 29: MDS diagram for Change in Practice in the Inquiry Classroom as shown by matched pairs, per country (* denotes responses after teacher education programme)

Component Questions

Examining in more detail the statistically significant changes to responses for each component question by each cohort, shows that there are several significant shifts (see Table A2.4 in Appendix 2), as follows, given for each statement:

- If a student investigation leads to an unexpected result I always tell the students the right answer/result – shift in cohort C from uncertain/agree to disagree and shift in cohort F to more strongly agree;
- I am unsure how to ask students higher order questions that promotes thinking – shift in cohort B from uncertain to slight agreement and shift in cohort D to more agreement;
- I have sufficient knowledge of science to implement an inquiry lesson effectively – two cohorts (B and F) shifted from being uncertain to agreeing with this statement, while cohort C shifted from being uncertain to disagreeing with this statement.

This section seems to indicate that there is ambiguity in terms of practice in the classroom in terms of obtaining the 'right' results in student investigations. The statement itself could be ambiguous as it may differ if the investigation was a set investigation that was curriculum bound or an open investigation. Having sufficient knowledge of science and also the ability to ask higher order questions are two areas that highlight differences between cohorts of teachers.

Teacher Experience Level

From MDS analysis of the overall teacher cohort based on their level of experience in inquiry (as described earlier, analysed in Figure A2.4 in Appendix 2 and given in Figure 30), the BE cohort have moved towards a middle position showing that there has been a change in attitude towards inquiry practices in the classroom. The SE cohort shows a small shift towards inquiry practices.

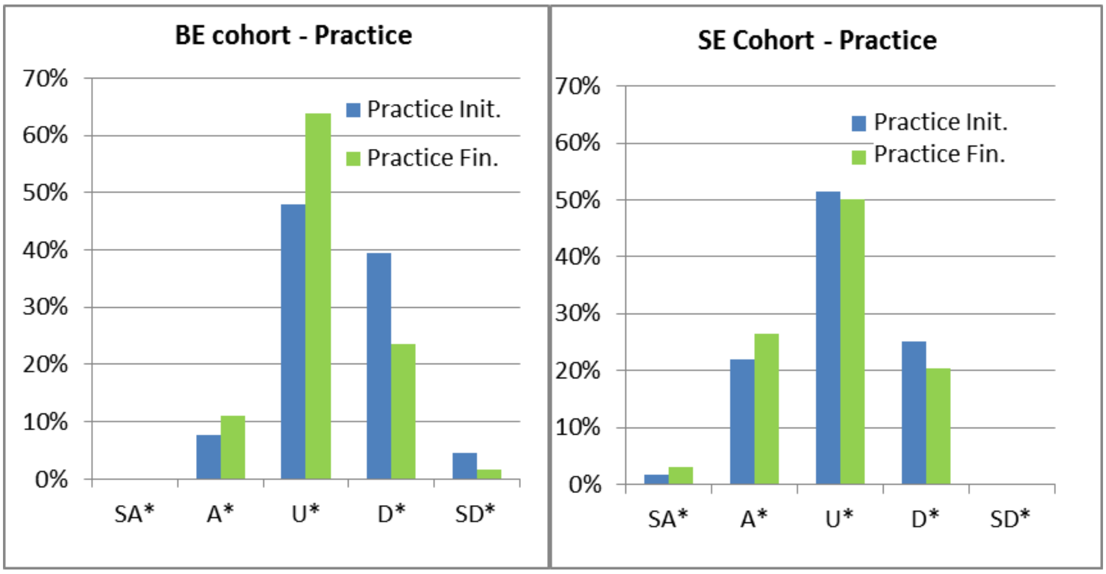


Figure 30: Numbers of teachers in each category, before and after the TEP for BE and SE cohorts (Practice) (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

Key conclusion

After the TEP, many cohorts have changed their attitudes towards their abilities to ask higher order questions that promote thinking in students and also their confidence in their own science knowledge. This highlights that these areas must continue to be addressed in TEPs.

2.5 Personal skills in relation to inquiry

Overview

Changes in the personal attributes of teacher cohorts were determined by conducting an MDS analysis on each matched pair's responses to the following questions:

- 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.

The MDS plot is shown in Figure 31.

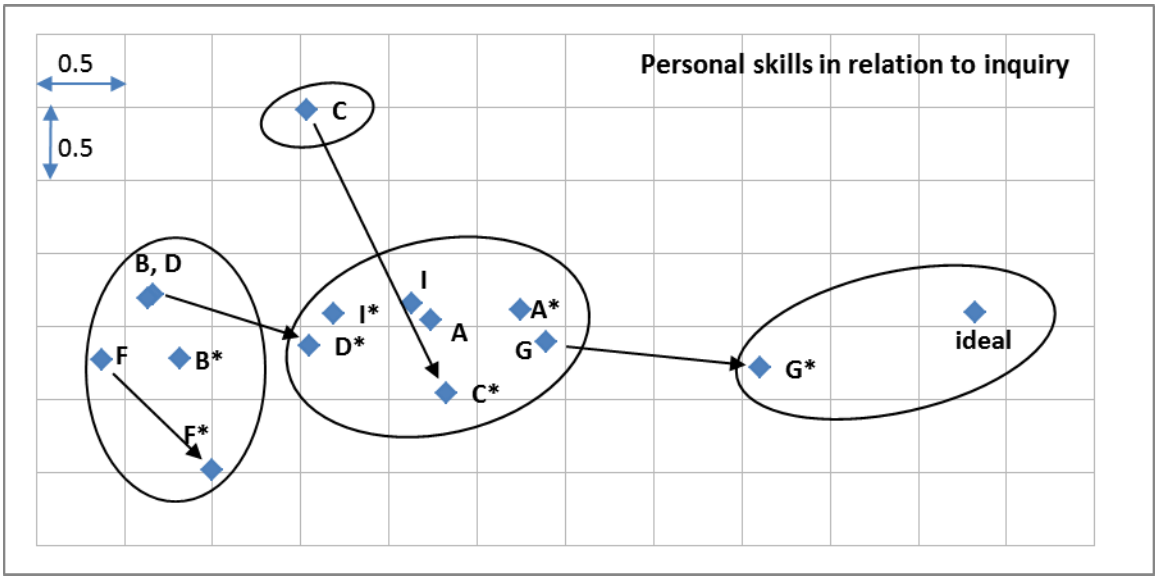


Figure 31: MDS diagram for Change in Personal skills as shown by matched pairs(cohort H was not included in this analysis as answers were incomplete)

It is clear that there is a wide spread of responses by the different cohorts initially and that most of the cohorts shift towards the ideal after the TEP. The ideal response was considered to be strong disagreement with each of the statements:

- 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.

In general, the further from the ideal, the more uncertain were the responses to these statements and the shift towards the ideal represents an increasing level of disagreement with one or more of the statements. The shift in cohort G was due mainly to a stronger disagreement with the statement on managing the classroom, while cohort C also shifted to a stronger disagreement with the statement on managing the classroom and also shifted to being comfortable with teaching areas of science that they have limited knowledge of. Cohort F found it difficult to manage a classroom with different activities. Cohort I shifted away from the ideal mainly due to a shift to greater uncertainty in managing a classroom with different activities and teaching with limited knowledge.

Component Questions

Examining each component question in detail, significant differences were found for the following cohorts as follows: (see Table A2.5 in Appendix 2)

- I find it difficult to manage a classroom where each student group is doing different activities – shift in cohort B from uncertain/agree to uncertain; also shift in cohort C from agreeing to disagree with this statement and in cohort F, from uncertain to disagree.
- I am uncomfortable with teaching areas of science that I have limited knowledge of – shift in cohort H from uncertain to disagree and in cohorts D, C and F from agree to uncertain;
- If I don't know the answers to students questions I feel inadequate as a teacher –shift in cohort C from disagree towards uncertain;
- I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself –shift in cohort C from disagree to uncertain.

Teacher Experience Level

Many of the statements above may be reflected by the experience level of the teacher, the MDS data was re-analysed based on teacher categorization as BE or SE. Data is given in Figure A2.5 in Appendix 2 and summarized in Figure 32. While the BE cohort have moved slightly closer to the ideal, the SE cohort appear to be moving somewhat away from the ideal. These areas are personal competencies of the individual teacher and relate to their self-efficacy and personality. There are many other factors that can contribute to these views that are not captured or measured in this survey and therefore these results should be viewed as informing the trend only.

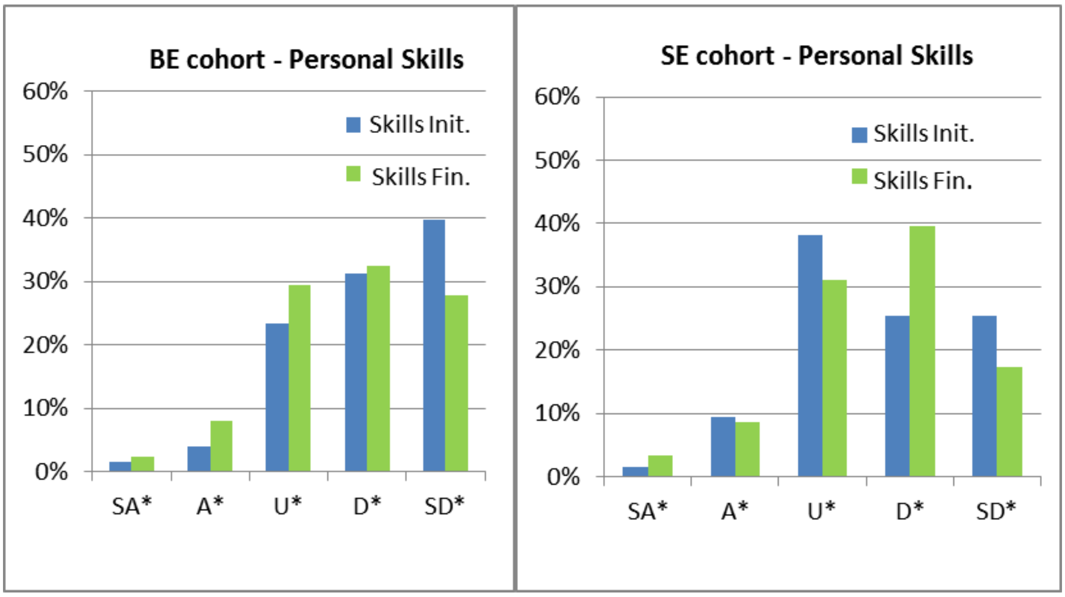


Figure 32: Numbers of teachers in each category, before and after the teacher education programme for BE and SE cohorts (Personal Skills) (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

Key conclusion

In this section, personal attributes of the teacher were determined and after the TEP, there is a general positive shift towards attitudes that are desirable in an inquiry classroom.

SECTION 3 Gender Effects

3.1 Overview

The initial questionnaire, completed at the start of the TEP, was completed by 458 teachers, while the final questionnaire was completed after the TEP by 233 of them. Of the initial cohort, 22.5% were male and 77.3% female. From the matched pairs (completed both questionnaires), 20.6% were male and 79.4% female.

As discussed in Section 1 and Section 2 above, differences have been seen between cohorts of teachers for many of main teacher attributes, such as understanding of inquiry, attitude towards inquiry etc. However, these differences have been explained in the main by differences in the experience level of the teachers with inquiry based teaching. In examining differences between responses to individual questions, the main differences again seem to be dependent on teacher inquiry experience level. 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 that may be attributed to gender, the group was subdivided into 4 groups, based on experience level and gender, namely: BE male, BE female, SE male and SE female (see Table 3.1). There are so few matched responses for the VE group that it was not appropriate to discuss this group. The MDS analysis was then carried out on each cohort and the change from the beginning of the TEP to after the programme was determined (as explained earlier in Section 2), for each attribute. The change in each cohort is discussed in Section 3.2 for BE cohort and Section 3.3 for SE cohort.

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

Cohort	Number of males	Number of females	% Male respondents
All	48	185	21
BE	29	133	18
SE	16	49	25
VE	3	3	50

3.2 Beginner Cohort (BE)

The change in matched pair responses, based on gender, for each attribute is given in Figure 33. In most cases, there is a significant shift towards the more ideal response. Each attribute will now be discussed briefly, in comparison to the changes already discussed in Section 2.

Understanding of Inquiry

From Figure 33a (Understanding of Inquiry), the mode for the male cohort was ‘agree with ideal’ initially but shifted significantly to ‘strongly agree with ideal’ after the TEP (Figure 33a). Females in this cohort were more uncertain or disagreed with the ideal response initially and their responses shifted to ‘agree’ and ‘strongly agree with ideal’. At the end of the TEP, 87% of the males were at ‘agree or strongly agree with ideal’, in comparison to 76% of the female cohort. In comparison to Figure 24, which showed that the BE cohort had increased their understanding of inquiry following the TEP, it is now clear from Figure 33a, that this increase is greater for the male cohort.

Care has to be exercised when interpreting this data as it is based on teacher’s self-classification in terms of their experience level of IBSE and also their interpretation of the Likert responses of e.g. ‘agree’ vs ‘strongly agree’ etc.

Attitude to Inquiry

The BE cohort have shown a shift towards more ideal responses in terms of their attitudes to inquiry (Figure 26). There is a bigger shift in the male cohort (Figure 33b), from 76% of males uncertain to 64 % at 'agree or strongly agree with ideal' after the TEP. After the TEP, there seems to be a greater proportion of females who are still uncertain (49%) in comparison to males (32%); however, there is also a shift in the female group towards the ideal response.

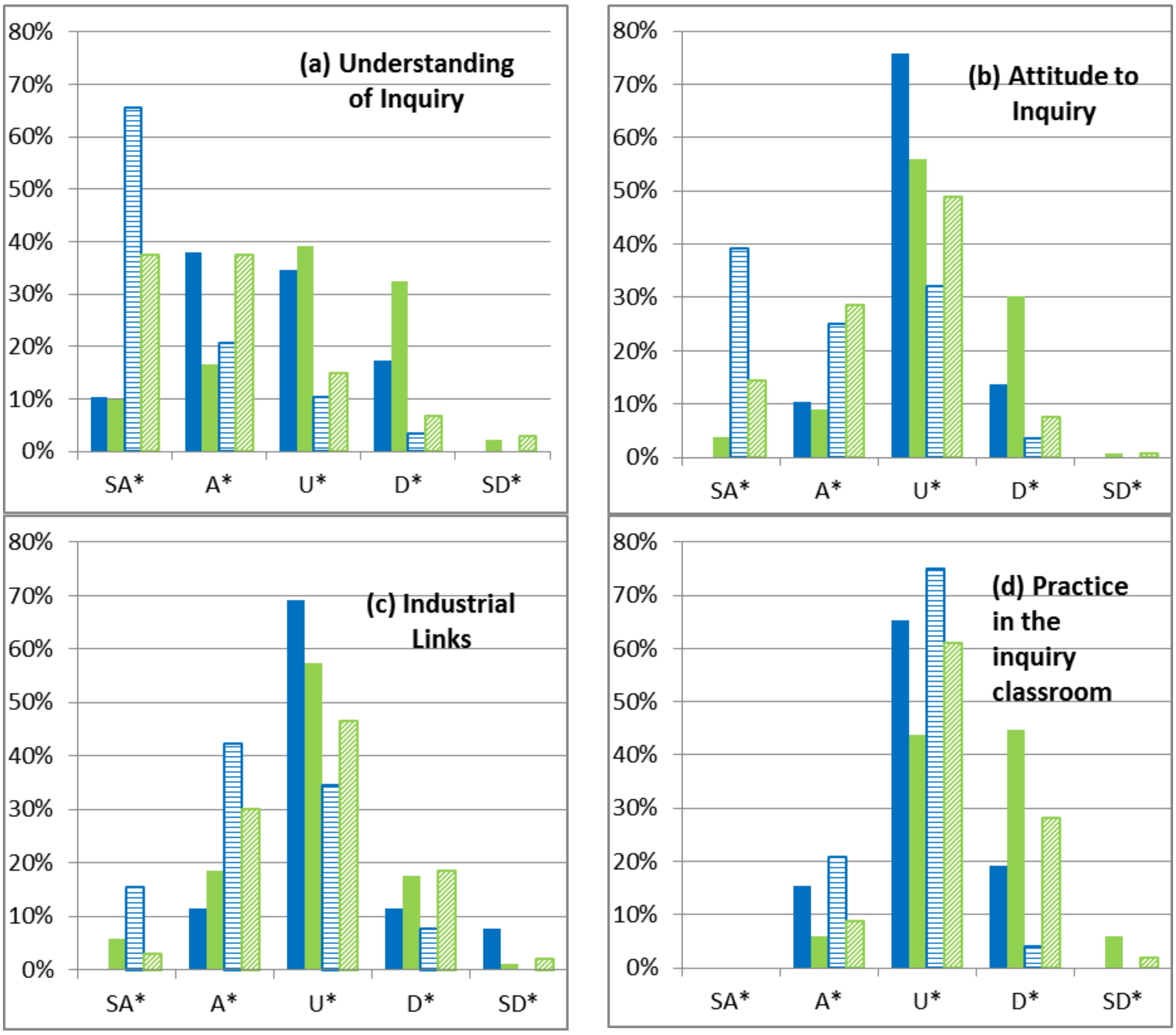
Industrial Links

A small shift was evident in the overall teacher cohort in terms of their understanding of industrial links (Figure 28). This shift is also evident for both the male and female cohorts (Figure 33c), with the modal response for male group shifting from 'uncertain' to agree with ideal' and that for the females remaining as 'uncertain'. However, 24% of the female cohort were responding either 'agree or strongly agree with ideal' even before the TEP and this increased to 33% after the TEP. The male cohort increased to 57% at 'agree or strongly agree with ideal' after the TEP, but only 12% were at this level initially. Therefore it seems that in terms of Industrial links, the views of the male cohort shifted more than the female group; however, more of the female group were at the ideal anyway.

Practice in the Inquiry Classroom *and* Personal Skills in relation to Inquiry

In terms of practice in the classroom, the mode for both male and female, before and after the TEP remained unchanged, with a slight decrease in those that disagree with the ideal response. With regard to the personal skills in relation to inquiry, again the male cohort have moved somewhat to a mode of 'uncertain' in their responses while the female cohort has remained relatively unchanged.

Throughout this section, there is a definite shift towards strongly agreeing or agreeing with the ideal responses for both male and female BE teachers, in terms of their understanding of inquiry, their attitudes to inquiry and industrial links. With regards to the other attributes of practice in the classroom and personal skills, this shift is not as obvious. In all cases, as stated above, the numbers of teachers involved in each cohort is small and therefore these trends should be treated with caution. Larger cohorts would be required to determine if these gender effects were significant.



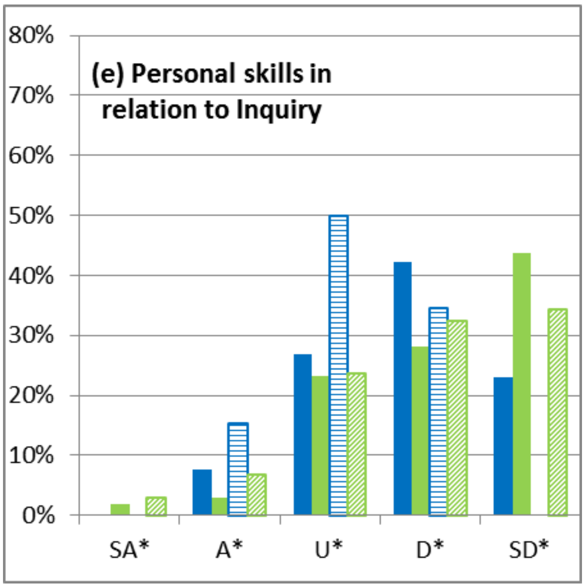
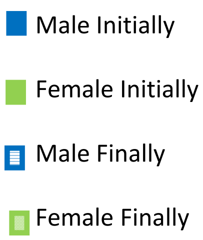


Figure 33: The change in matched pair responses for each attribute, based on gender for BE cohort (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)



3.3 Some Experience Cohort (SE)

The change in matched pair responses, based on gender, for each attribute for the SE cohort of teachers is given in Figure 34. The number of matched cases for the SE cohort is very small for the male group and so the data below should be considered cautiously, as further analysis with a larger cohort would be necessary to determine if these trends are significant. From Figure 34a (Understanding of Inquiry), there is a trend for both male and female cohorts to shift towards greater agreement to the ideal response after the TEP. Again in terms of their attitudes to inquiry (Figure 34b), there is a tendency towards more agreement with the ideal response after completion of the TEP. The male cohort is more in agreement than the female group who are somewhat more uncertain in their responses.

The responses to the questions on industrial links and practice in the classroom are quite varied and there is no real trend in responses based on gender. As the numbers are low, small changes can be over emphasized and therefore in these categories, there is really no distinction. There is no data for Personal skills as this section was not completed by a group of male respondents.

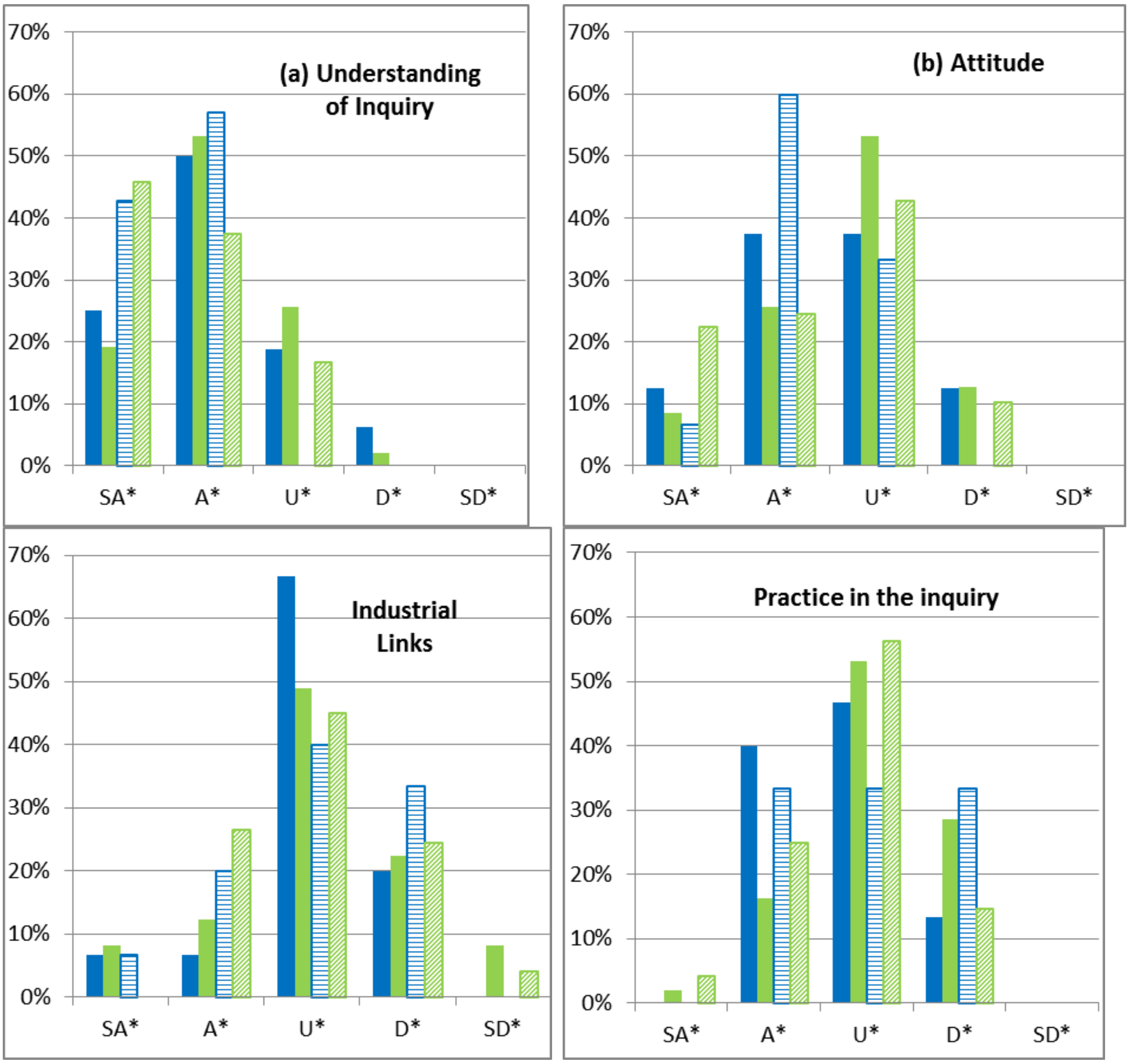


Figure 34: The change in matched pair responses for each attribute, based on gender for BE cohort (SA*, A*, U*, D*, SD* abbreviate for strongly agree with ideal, agree with ideal, uncertain, disagree with ideal, strongly disagree with ideal, respectively)

Male Initially Male Finally Female Initially Female Finally

3.4 Key conclusion

For the BE cohort, the male cohort seem to have moved in greater numbers towards the ideal than the female group in each of the attributes. This is not as clear in the SE cohort.

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', or 'Almost Never' to 'Almost Always', depending on the question.

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 before and after participating in ESTABLISH Teacher Education programmes. 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

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:

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

in relation to the initial profile of the teachers and also to determine the change that occurs after completing the TEP.

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). The responses to particular attributes differs depending on their experience level. Teachers' understanding of inquiry was strongly influenced by the experience level of teachers, with cohorts containing a large proportion of SE and VE teachers fully understanding inquiry and the role of teachers and students in an inquiry classroom. In terms of recognising barriers to implementing inquiry such as time-pressures and student ability, BE cohorts were more uncertain towards recognising these barriers while experienced teachers felt that these issues were not so important. With regard to industrial links, teachers value a broader view of science in the classroom, with over 80% of the BE teachers (and 94% of the VE teachers) stating that they want their 'students to know about the latest developments and applications of science and engineering'.

There are large differences seen with classroom practice, with the BE cohort finding practices associated with inquiry more difficult – such as: BE teachers are more likely to 'tell the students the right answer/result' in an investigation and are more uncertain of how to ask 'higher order questions that promotes thinking'. Managing a classroom where each student group is doing different activities is difficult for 24% of the VE group and up to 46% of the BE group. While many feel uncomfortable with teaching areas of science that they have limited knowledge of (45%VE and 60% BE), many are also 'uncomfortable with asking questions, in my class, where I am unsure of the answer myself' (34% BE and 21% VE). Self-perception as a teacher is also important but almost one-fifth of the group with feelings of inadequacy if they do not know answers to student questions.

In terms of student control in an inquiry classroom, the average response from the group implies that students <u>sometimes</u> determine the research question, design investigations, conduct investigations, decide which data to collect and draw conclusions. This may suggest that the type of inquiry used tends to be more 'guided' rather than 'open'.

Following the TEP, almost all cohorts have increased their understanding of inquiry and their understanding of the roles of teacher and student in an inquiry classroom. The bigger shift in understanding has been in those who classify themselves as beginners in IBSE. Attitudes to inquiry have also shifted towards the ideal response by the majority of the teacher cohorts and particularly, the effect seems to be more significant on the BE cohort. Small shifts in terms of Industrial links were evident by most of the teacher cohorts after the TEP, these changes occurred for both teachers who were beginners in inquiry and those with some experience. Many cohorts have changed their attitudes towards their abilities to ask higher order questions that promote thinking in students and also their confidence in their own science knowledge. With regards to teachers' skills, there is a general positive shift towards attitudes that are desirable in an inquiry classroom.

From analysis of the gender groups at different levels of experience with IBSE, the BE groups moved closer to the ideal responses and there was a tendency for the male cohort to move in greater numbers than the female cohort, particularly for understanding of inquiry and attitude to inquiry. For the other attributes, there is no significant differences between male and female cohorts. Also there are no main differences between male and female cohorts for the SE cohorts.

The TEP seems to be effective in increasing the teachers understanding of inquiry and the role of the teacher and student in the inquiry classroom. Also the attitudes to inquiry have shifted after the TEP to more positive towards inquiry. After the TEP, many cohorts have changed their attitudes towards their abilities to ask higher order questions that promote thinking in students and also their confidence in their own science knowledge. Finally the shifts observed are bigger for those who were self-classified as Beginners, with smaller shifts seen with those with SE or VE.

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 = strongly disagree, disagree, uncertain, agree, strongly agree).

Statement item	Group	SD	D	U	A	SA	Mean
11. I don't fully understand inquiry based science education	B	8%	26%	28%	32%	5%	3.00
	SE	18%	59%	12%	9%	1%	2.17
	VE	70%	24%	0%	3%	0%	1.34
12. I don't fully understand my role as a teacher in an inquiry classroom	B	8%	43%	24%	23%	1%	2.65
	SE	20%	56%	14%	7%	1%	2.12
	VE	67%	27%	0%	3%	0%	1.38
13. I don't fully understand the role of the students in an inquiry classroom	B	10%	44%	24%	21%	2%	2.61
	SE	18%	61%	8%	9%	1%	2.12
	VE	73%	21%	0%	3%	0%	1.31

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

Statement item	Group	SD	D	U	A	SA	Mean
14. I think inquiry takes up too much classroom time for me to implement.	B	4%	19%	30%	38%	8%	3.28
	SE	8%	33%	21%	29%	7%	2.94
	VE	48%	24%	6%	15%	0%	1.87
15. The use of inquiry is appropriate to achieving the aims of the curriculum.	B	1%	9%	30%	49%	10%	3.59
	SE	0%	7%	20%	55%	16%	3.80
	VE	12%	3%	6%	27%	48%	4.00
16. Inquiry based teaching is only suitable for very capable students.	B	11%	48%	26%	13%	3%	2.48
	SE	23%	50%	16%	10%	2%	2.19
	VE	52%	27%	9%	6%	3%	1.78

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

Statement item	Group	SD	D	U	A	SA	Mean
Q37 I want my students to know about the latest developments and applications of science and engineering.	B	0%	2%	3%	49%	31%	4.29
	SE	0%	3%	7%	51%	36%	4.22
	VE	0%	0%	3%	39%	55%	4.53
Q38 I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom.	B	0%	5%	29%	41%	10%	3.64
	SE	0%	9%	15%	59%	15%	3.81
	VE	0%	0%	0%	67%	33%	4.33
Q39 I often show students the relevance of science in industry.	B	0%	7%	7%	40%	31%	4.10
	SE	1%	14%	13%	57%	14%	3.71
	VE	0%	12%	12%	42%	33%	3.97
Q40 My students understand the importance of science and technology for our society.	B	0%	8%	22%	31%	24%	3.81
	SE	1%	8%	24%	51%	14%	3.70
	VE	0%	0%	21%	61%	15%	3.94
Q41 If I had more information about	B	0%	2%	13%	45%	24%	4.10

industrial processes, I would use it in my teaching.	SE	0%	5%	14%	56%	23%	3.98
	VE	0%	0%	12%	55%	33%	4.21

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

Statement item	Group	SD	D	U	A	SA	Mean
Q67. If a student investigation leads to an unexpected result I always tell the students the right answer/result.	B	2%	19%	10%	46%	8%	3.47
	SE	7%	32%	20%	34%	5%	2.98
	VE	6%	33%	27%	18%	12%	2.97
Q69 I am unsure how to ask students higher order questions that promotes thinking.	B	6%	33%	15%	27%	4%	2.88
	SE	14%	47%	20%	18%	0%	2.43
	VE	27%	61%	6%	6%	0%	1.91
Q70 I have sufficient knowledge of science to implement an inquiry lesson effectively	B	2%	10%	41%	27%	4%	3.24
	SE	2%	6%	25%	56%	8%	3.62
	VE	3%	0%	18%	52%	27%	4.00

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

Statement item	Group	SD	D	U	A	SA	Mean
Q68 I find it difficult to manage a classroom where each student group is doing different activities.	B	4%	23%	12%	33%	13%	3.34
	SE	13%	40%	21%	21%	5%	2.64
	VE	30%	42%	3%	24%	0%	2.21
Q71 I am uncomfortable with teaching areas of science that I have limited knowledge of.	B	3%	14%	9%	50%	10%	3.59
	SE	7%	24%	14%	49%	5%	3.21
	VE	12%	27%	15%	42%	3%	2.97
Q72 If I don't know the answers to students questions I feel inadequate as a teacher	B	22%	32%	11%	17%	3%	2.37
	SE	24%	50%	12%	12%	1%	2.16
	VE	30%	45%	6%	18%	0%	2.12
Q73. I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself.	B	12%	23%	16%	22%	12%	2.98
	SE	14%	43%	13%	24%	5%	2.62
	VE	27%	39%	12%	18%	3%	2.30

Table A1.6: Responses to questions Asking Research Questions, based on individual teacher experience in IBSE (AN, SE, SO, O, AA = almost never, seldom, sometimes, often and almost always)

* With permission from Principles of Scientific Inquiry – Teacher (PSI-T) by Campbell, Abd-hamid and Chapman (2010)

Statement item	Group	AN	SE	SO	O	AA	Mean
Q47 Students formulate questions which can be answered by investigations. *	BE	8%	24%	36%	27%	4%	2.94
	SE	4%	25%	46%	21%	3%	2.94
	VE	3%	15%	30%	42%	9%	3.39
Q48 Student research questions are used to determine the direction and focus of the lab*	BE	17%	25%	38%	15%	4%	2.63
	SE	14%	33%	34%	15%	1%	2.57
	VE	6%	12%	39%	36%	6%	3.24
Q49 Students framing their own research	BE	9%	15%	36%	28%	10%	3.14

questions are important. *	SE	4%	13%	33%	35%	9%	3.32
	VE	0%	6%	33%	33%	21%	3.74
Q50 Time is devoted to refining student questions so that they can be answered by investigations. *	BE	13%	33%	33%	19%	2%	2.63
	SE	11%	29%	35%	20%	3%	2.73
	VE	0%	18%	39%	36%	6%	3.30

Table A1.7: Responses to questions Designing Investigations, based on individual teacher experience in IBSE (AN, SE, SO, O, AA = almost never, seldom, sometimes, often and almost always)
* With permission from Principles of Scientific Inquiry – Teacher (PSI-T) by Campbell, Abd-hamid and Chapman (2010)

Statement item	Group	AN	SE	SO	O	AA	Mean
Q51 Students are given step-by-step instructions before they conduct investigations. *	BE	4%	10%	19%	32%	33%	3.83
	SE	1%	8%	31%	42%	16%	3.64
	VE	6%	27%	36%	21%	6%	2.94
Q52 Students design their own procedures for investigations. *	BE	28%	37%	23%	7%	3%	2.20
	SE	11%	34%	41%	12%	1%	2.57
	VE	9%	15%	36%	27%	12%	3.18
Q53 Students engage in the critical assessment of the procedures that are employed when they conduct investigations. *	BE	13%	43%	27%	14%	3%	2.50
	SE	4%	31%	44%	17%	3%	2.83
	VE	3%	12%	27%	33%	18%	3.55
Q54 Students justify the appropriateness of the procedures that are employed when they conduct investigations. *	BE	14%	36%	31%	13%	3%	2.53
	SE	8%	35%	35%	17%	2%	2.69
	VE	3%	15%	33%	30%	15%	3.41

Table A1.8: Responses to questions Conducting Investigations, based on individual teacher experience in IBSE (AN, SE, SO, O, AA = almost never, seldom, sometimes, often and almost always)
* With permission from Principles of Scientific Inquiry – Teacher (PSI-T) by Campbell, Abd-hamid and Chapman (2010)

Statement item	Group	AN	SE	SO	O	AA	Mean
Q55 Students conduct their own procedures for an investigation. *	BE	20%	35%	28%	8%	8%	2.48
	SE	11%	28%	35%	19%	5%	2.79
	VE	6%	6%	42%	24%	18%	3.44
Q56 The investigation is conducted by the teacher in front of the class. *	BE	12%	14%	28%	33%	11%	3.17
	SE	17%	20%	37%	21%	3%	2.74
	VE	33%	9%	42%	6%	9%	2.48
Q57 Students actively participate in investigations as they are conducted. *	BE	2%	8%	36%	33%	19%	3.60
	SE	0%	3%	22%	48%	23%	3.92
	VE	0%	0%	18%	36%	45%	4.27
Q58 Each student has a role as investigations are conducted. *	BE	7%	20%	26%	30%	15%	3.27
	SE	5%	11%	25%	36%	21%	3.58
	VE	3%	9%	9%	39%	39%	4.03

Table A1.9: Responses to questions Collecting Data, based on individual teacher experience in IBSE (AN, SE, SO, O, AA = almost never, seldom, sometimes, often and almost always)
* With permission from Principles of Scientific Inquiry – Teacher (PSI-T) by Campbell, Abd-hamid and Chapman (2010)

Statement item	Group	AN	SE	SO	O	AA	Mean
Q59 Students determine which data to	BE	17%	29%	37%	12%	4%	2.57

collect. *	SE	5%	31%	37%	21%	3%	2.85
	VE	3%	21%	27%	30%	15%	3.34
Q60 Students take detailed notes during each investigation along with other data they collect. *	BE	9%	16%	29%	32%	14%	3.26
	SE	4%	17%	27%	35%	14%	3.40
	VE	3%	9%	27%	39%	18%	3.63
Q61 Students understand why the data they are collecting is important. *	BE	6%	12%	43%	29%	9%	3.23
	SE	0%	7%	32%	45%	13%	3.66
	VE	0%	3%	27%	48%	21%	3.88
Q62 Students decide when data should be collected in an investigation. *	BE	16%	47%	22%	14%	1%	2.37
	SE	8%	30%	38%	17%	4%	2.78
	VE	0%	21%	42%	27%	3%	3.10

Table A1.10: Responses to questions Drawing Conclusions, based on individual teacher experience in IBSE (AN, SE, SO, O, AA = almost never, seldom, sometimes, often and almost always)

* With permission from Principles of Scientific Inquiry – Teacher (PSI-T) by Campbell, Abd-hamid and Chapman (2010)

Statement item	Group	AN	SE	SO	O	AA	Mean
Q63 Students develop their own conclusions for investigations	BE	2%	21%	26%	30%	5%	3.18
	SE	0%	12%	27%	44%	16%	3.64
	VE	0%	0%	6%	70%	24%	4.18
Q64 Students consider a variety of ways of interpreting evidence when making conclusions. *	BE	11%	34%	28%	9%	2%	2.49
	SE	1%	30%	39%	21%	7%	3.02
	VE	0%	12%	42%	36%	9%	3.42
Q65 Students connect conclusions to scientific knowledge. *	BE	5%	18%	34%	25%	2%	3.04
	SE	0%	9%	40%	38%	11%	3.51
	VE	0%	3%	24%	55%	18%	3.88
Q66Students justify their conclusions. *	BE	4%	24%	28%	25%	3%	2.98
	SE	2%	19%	25%	39%	14%	3.45
	VE	0%	9%	30%	27%	33%	3.85

Appendix 2

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

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

	A	B	C	D	E	F	G	H	I
11. I don't fully understand inquiry based science education	2.56/ 1.67	2.68/ 1.48	2.57/ 1.56	2.35/ 2.00	4.06/ 4.03	2.53/ 2.11	1.17/ 1.00	2.10/ 1.75	2.06/ 1.68
Q12 I don't fully understand my role as a teacher in an inquiry classroom	2.78/ 1.67	2.70/ 1.58	2.20/ 1.33	2.41/ 1.76	2.48/ 2.27	2.42/ 1.74	1.17/ 1.00	2.22/ 1.88	2.16/ 1.84
Q13 I don't fully understand the role of the students in an inquiry classroom	2.44/ 1.67	2.61/ 1.42	2.00/ 1.15	2.12/ 1.88	3.06/ 3.12	2.26/ 1.74	1.17/ 1.00	2.40/ 1.86	2.16/ 1.73

	whole group	B	SE	VE
11. I don't fully understand inquiry based science education	2.70/1.97	3.02/2.06	1.94/1.78	2.00/1.60
Q12 I don't fully understand my role as a teacher in an inquiry classroom	2.41/1.67	2.58/1.71	2.02/1.56	2.00/1.60
Q13 I don't fully understand the role of the students in an inquiry classroom	2.38/1.70	2.57/1.75	1.95/1.58	1.83/1.60

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

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

	A	B	C	D	E	F	G	H	I
Q14 I think inquiry takes up too much classroom time for me to implement.	2.78/ 2.44	3.09/ 2.67	2.96/ 1.69	3.24/ 2.76	4.06/ 4.18	3.89/ 3.53	1.80/ 1.33	2.33/ 2.13	2.89/ 2.74
Q15 The use of inquiry is appropriate to achieving the aims of the curriculum.	3.56/ 3.67	3.55/ 4.03	3.59/ 4.46	3.53/ 3.53	3.61/4 .24	3.63/ 3.58	4.50/ 4.33	3.60/ 3.75	4.00/ 4.21
Q16 Inquiry based teaching is only suitable for very capable students.	2.89/ 2.00	2.52/ 1.91	2.20/ 1.46	2.24/ 1.88	3.24/2 .58	3.05/ 2.32	2.17/ 1.67	1.60/ 1.75	1.89/ 1.79

	whole group	B	SE	VE
Q14 I think inquiry takes up too much classroom time for me to implement.	3.19/2.68	3.38/2.73	2.79/ 2.55	2.17/ 2.40
Q15 The use of inquiry is appropriate to achieving the aims of the curriculum.	3.64/4.09	3.53/4.14	3.88/ 3.97	3.83/ 4.00
Q16 Inquiry based teaching is only suitable for very capable students.	2.48/1.91	2.56/1.89	2.31/2.00	2.33/ 1.60

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

Red shading and text signifies significant differences in mean at 95% level based on Wilcoxon Signed Rank.	A	B	C	D	F	G	H	I
Q37 I want my students to know about the latest developments and applications of science and engineering.	4.33/ 4.44	4.33/ 4.30	4.33/ 4.65	4.47/ 4.41	4.21/ 4.37	4.17/ 4.17	3.56/ 3.50	4.56/ 4.47
Q38 I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom.	4.00/ 4.00	3.32/ 3.36	3.89/ 4.33	3.82/ 4.12	3.53/ 3.16	3.17/ 3.50	4.00/ 4.00	4.21/ 4.26
Q39 I often show students the relevance of science in industry.	4.11/ 4.33	4.39/ 3.94	4.30/ 4.43	3.88/ 4.35	3.11/ 3.89	2.67/ 2.83	3.44/ 3.63	4.32/ 4.16
Q40 My students understand the importance of science and technology for our society.	3.67/ 4.00	4.62/ 3.61	3.11/ 4.06	4.24/3. 76	3.00/ 3.37	3.67/ 4.17	4.11/ 3.88	3.79/ 3.74
Q41 If I had more information about industrial processes, I would use it in my teaching.	4.33/ 4.44	4.09/ 4.12	4.06/ 4.37	4.00/ 4.18	3.53/ 3.95	4.00/ 4.17	3.89/ 3.50	4.11/ 4.26

	whole group	B	SE	VE
Q37 I want my students to know about the latest developments and applications of science and engineering.	4.31/4.40	4.28/4.45	4.38/4.30	4.33/4.40
Q38 I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom.	3.68/3.82	3.60/3.84	3.77/3.75	4.50/4.20
Q39 I often show students the relevance of science in industry.	4.09/4.10	4.24/4.19	3.81/3.92	3.67/4.00
Q40 My students understand the importance of science and technology for our society.	3.85/3.78	3.90/3.80	3.72/3.69	4.17/4.40
Q41 If I had more information about industrial processes, I would use it in my teaching.	4.02/4.18	4.05/4.21	3.97/4.13	4.20/3.98

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

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

	A	B	C	D	F	G	H	I
Q67 If a student investigation leads to an unexpected result I always tell the students the right answer/result.	2.89/ 2.67	3.91/ 3.91	3.50/ 1.7	2.71/ 2.71	3.68/ 4.00	3.17/ 3.00	2.56/ 2.13	2.58/ 2.26
Q69 I am unsure how to ask students higher order questions that promotes thinking.	2.11/ 1.78	3.42/ 2.82	2.26/ 2.04	2.47/ 2.00	3.16/ 2.95	2.00/ 2.17	2.22/ 3.88	1.89/ 1.79
Q70 I have sufficient knowledge of science to implement an inquiry lesson effectively	3.33/ 3.78	2.91/ 3.52	3.46/ 2.28	3.41/ 3.59	3.26/ 3.74	4.17/ 3.80	3.56/ 2.14	3.37/ 3.95

	whole group	B	SE	VE
Q67 If a student investigation leads to an unexpected result I always tell the students the right answer/result.	3.42/2.90	3.56/2.93	3.19/2.84	2.83/2.80
Q69 I am unsure how to ask students higher order questions that promotes thinking.	2.70/2.43	2.91/2.54	2.34/2.28	2.00/1.40
Q70 I have sufficient knowledge of science to implement an inquiry lesson effectively	3.27/3.21	3.15/3.02	3.52/3.54	3.17/4.00

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

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

	A	B	C	D	F	G	H	I
Q68 I find it difficult to manage a classroom where each student group is doing different activities.	2.33/ 2.11	3.45/ 2.97	3.74/ 1.89	3.35/ 2.76	3.11/ 2.16	2.00/ 1.33	2.22/ 2.00	2.42/ 2.63
Q71 I am uncomfortable with teaching areas of science that I have limited knowledge of.	3.11/ 2.78	3.67/ 3.70	3.72/ 3.02	3.94/ 3.12	4.11/ 3.74	2.50/ 1.67	3.00/ 2.13	3.21/ 3.47
Q72 If I don't know the answers to students questions I feel inadequate as a teacher	2.11/ 2.00	2.62/ 2.79	1.91/ 2.35	2.75/ 2.41	3.21/ 3.21	1.83/ 1.67	2.00/ 2.57	1.89/ 2.26
Q73 I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself.	2.56/ 2.22	3.58/ 3.58	2.06/ 2.74	3.35/ 3.29	3.53/ 3.63	2.50/ 1.83	2.11/ na	2.74/ 2.84

	whole group	B	SE	VE
Q68 I find it difficult to manage a classroom where each student group is doing different activities.	3.24/2.42	3.45/2.55	2.89/2.19	2.50/2.00
Q71 I am uncomfortable with teaching areas of science that I have limited knowledge of.	3.61/3.28	3.70/3.43	3.45/3.05	3.33/2.40
Q72 If I don't know the answers to students questions I feel inadequate as a teacher	2.35/2.55	2.37/2.51	2.29/2.68	2.50/1.80
Q73 I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself.	2.91/3.13	3.03/3.23	2.75/2.97	2.33/2.40

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			
	Before	Before	After	After	Before	Before	After	After
	M	F	M	F	M	F	M	F
SA*	10%	10%	66%	38%	25%	19%	43%	46%
A*	38%	17%	21%	38%	50%	53%	57%	38%
U*	34%	39%	10%	15%	19%	26%	0%	17%
D*	17%	32%	3%	7%	6%	2%	0%	0%
SD*	0%	2%	0%	3%	0%	0%	0%	0%

Attitude to Inquiry								
SA*	0%	4%	39%	14%	13%	9%	7%	22%
A*	10%	9%	25%	29%	38%	26%	60%	24%
U*	76%	56%	32%	49%	38%	53%	33%	43%
D*	14%	30%	4%	8%	13%	13%	0%	10%
SD*	0%	1%	0%	1%	0%	0%	0%	0%

Industrial links								
SA*	0%	6%	15%	3%	7%	8%	7%	0%
A*	12%	18%	42%	30%	7%	12%	20%	27%
U*	69%	57%	35%	47%	67%	49%	40%	45%
D*	12%	17%	8%	18%	20%	22%	33%	24%
SD*	8%	1%	0%	2%	0%	8%	0%	4%

Practice in Inquiry Classroom								
SA*	0%	0%	0%	0%	0%	2%	0%	4%
A*	15%	6%	21%	9%	40%	16%	33%	25%
U*	65%	44%	75%	61%	47%	53%	33%	56%
D*	19%	45%	4%	28%	13%	29%	33%	15%
SD*	0%	6%	0%	2%	0%	0%	0%	0%

Personal Skills								
SA*	0%	2%	0%	3%	0%	2%	0%	4%
A*	8%	3%	15%	7%	20%	6%	9%	9%
U*	27%	23%	50%	24%	47%	35%	27%	32%
D*	42%	28%	35%	32%	20%	27%	64%	34%
SD*	23%	44%	0%	34%	13%	29%	0%	21%

Appendix 4

INSERVICE TEACHER QUESTIONNAIRE - A

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

Section A: Background Information

1. Name: ______________________________ **2. Age:** ____________________________

3. Sex: Male Female **4. School:** __________________________

5. Type of school: All boys All girls Mixed

6. Years of Teaching Experience: ____

7. Do you have technical assistance available in your school? Y: N:

8. Qualification(s):____

9. Teaching Subject(s):

Integrated Science Chemistry Physics Biology Maths

10. 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 your level of agreement with each of the following statements.

	Strongly Disagree	Disagree	Uncertai n	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 inquiry based teaching?

____

14. If you have used inquiry based teaching, what percentage of teaching time do you spend

____

15. Give an example of how you have used inquiry based teaching.

____

Section C. Attitudes and views towards science and teaching science:

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

In my opinion…	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
16. Scientific theories (e.g. atomic theory) are constant unchanging bodies of knowledge.					
17. Scientific knowledge is primarily focused on knowing facts					

In my opinion, when teaching science...	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
18. Developing students' specific content knowledge is much more important than developing their thinking and reasoning processes.					
19. Teaching is more effective when all students are doing the same activity at the same time.					
20. It is easy to teach the curriculum using inquiry based teaching.					
21. Good teachers ask higher order questions.					
22. Good teachers focus on curriculum content only.					
23. Good teachers use student questions to guide their teaching.					
24. Good teachers present facts and then explain them.					
25. Good teachers allow students to develop their own investigation/research questions.					
26. Students need to know a lot of facts before they can participate in inquiry activities.					
27. My goal is to transfer factual knowledge to the students.					
28. Good teachers encourage student discussion on scientific topics relevant to everyday life.					
29. I am happy with my current teaching methods.					
30. I am open to trying different methodologies in my teaching.					
31. I feel apprehensive about changing my current teaching practice.					
32. I want my students to know about the latest developments and applications of science and engineering.					
33. I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom.					
34. I often show students the relevance of science in industry.					
35. My students understand the importance of science and					

technology for our society.					
36. If I had more information about industrial processes, I would use it in my teaching.					

Section D. Classroom Practice/Classroom Environment

Select a class group in your mind. In relation to this class group, for each of the following statements, please indicate the frequency of implementation:

Class group: _______________ **Age Group:_____________** **Subject:___________________**

	Almost never	Seldom	Some-times	Often	Almost always
37. Students learn how science can be a part of their out-of-school life.					
38. Students learn that the views of science have changed over time.					
39. Students ask each other to explain their ideas.					
40. Students learn that scientific knowledge can be questioned.					
41. Students pay attention to each other's ideas.					
42. Students formulate questions which can be answered by investigation*					
43. Student research questions are used to determine the direction and focus of the lab. *					
44. Students framing their own research questions are important.*					
45. Time is devoted to refining student questions so that they can be answered by investigations. *					
46. Students are given step-by-step instructions before they conduct investigations. *					
47. Students design their own procedures for investigations. *					
48. Students engage in the critical assessment of the procedures that are employed when they conduct investigations. *					
49. Students justify the appropriateness of the procedures that are employed when they conduct investigations. *					
50. Students conduct their own procedures of an investigation. *					
51. The investigation is conducted by the teacher in front of the class. *					
52. Students actively participate in investigations as they are conducted. *					
53. Each student has a role as investigations are conducted. *					
54. Students detemine which data to collect. *					
55. Students take detailed notes during each investigation along with other data they collect. *					
56. Students understand why the data they are collecting is important. *					
57. Students decide when data should be collected in an investigation. *					
58. Students develop their own conclusions for investigations.*					
59. Students consider a variety of ways of interpreting evidence when making conclusions. *					
60. Students connect conclusions to scientific knowledge. *					
61. Students justify their conclusions. *					

Section E: Teaching Science

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

	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
62. If a student investigation leads to an unexpected result I always tell the students the right answer/result.					

63. I find it difficult to manage a classroom where each student group is doing different activities.					
64. I am unsure how to ask students higher order questions that promotes thinking.					
65. I have sufficient knowledge of science to implement an inquiry lesson effectively					
66. I am uncomfortable with teaching areas of science that I have limited knowledge of.					
67. If I don't know the answers to students questions I feel inadequate as a teacher					
68. I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself.					

Section F: Challenges in Inquiry Teaching

69. 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	

Many thanks for completing this questionnaire.

* With permission from Principles of Scientific Inquiry – Teacher (PSI-T) by Campbell, Abd-hamid and Chapman (2010)

INSERVICE 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. School: ______________________________

3. 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 your level of agreement with each of the following statements.

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
70. I don't fully understand inquiry-based science education					
71. I don't fully understand my role as a teacher in an inquiry classroom					
72. I don't fully understand the role of the students in an inquiry classroom					
73. I think inquiry takes up too much classroom time for me to implement.					
74. The use of inquiry is appropriate to achieving the aims of the curriculum.					
75. Inquiry-based teaching is only suitable for very capable students.					
76. Inquiry will never be my main teaching method					

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

____

____

78. If you have used inquiry based teaching, what percentage of your teaching time do you spend using it?

____

____

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

____

____

14. Outline what your students did during inquiry lessons.

____

____

Section C. Industrial Content Knowledge and Authentic Experiences

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

In my opinion, when teaching science,	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
15. I want my students to know about the latest developments and applications of science and engineering.					
16. I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom.					
17. I often show students the relevance of science in industry					

18. My students understand the importance of science and technology for our society.					
19. If I had more information about industrial processes, I would use it in my teaching.					

Section D. Teaching science

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

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

Section E: Challenges in Inquiry Teaching

27. 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	

Many thanks for completing this questionnaire. **1**