Staff and student opinions of the inclusion of practical work in higher education chemistry courses in England: what are the perceived objectives and outcomes?

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Abstract
Practical work is seen as an essential part of science courses. However, practical work is very resource intensive and in the current HE environment, in which academics will inevitably find themselves teaching more students with fewer resources, it is important to justify the cost in terms of educational benefit and so the objectives must be clear.

This report describes the results of a survey of students undertaking chemistry undergraduate courses and staff in Higher Education chemistry departments in England. These surveys aimed to ascertain the range of practical work being carried out, alongside staff and student opinions of practical work. It also examined the reasons why practical work is included in undergraduate courses and what students take away from participating.

Background
Chemistry is studied in almost 40 universities in England[1]. Within chemistry courses practical work is a key component with between 6 and 12 hours a week of students time being spent in the laboratory through a mix of timetabled and project work. With this high investment of time, it is essential that the learning from this experience is worthy of the input.

Practical work is often claimed to be essential to a chemistry course with little justification of why this is so[2]. This study aims to gain an insight into why staff and students think practical work is included in chemistry courses. It also aimed to examine what students actually take away from practical work and if this matches the objectives.

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Types of practical work
Domin discusses the different types of practical work style in use (expository, inquiry, discovery and problem based)[3]. These types vary depending on the outcome (pre-determined or undetermined), the approach (deductive or inductive) and procedure (given or student generated) (Table 1).

Table 1: Characteristics of the different types of practical work. Adapted from Domin[3]

Type	Approach	Procedure	Outcome
Expository	Given	Deductive	Known
Inquiry	Student-generated	Inductive	Unknown
Discovery	Given	Inductive	Known
Problem based	Student-generated	Deductive	Known

These different types of practical work use and develop different skills. They may also be suited to achieve different objectives[3] and be used at different stages in a university degree. Within this project, students have been asked to identify the type they predominately carry out and see if this relates to their opinions and experiences of practical work.

Expository
Within an expository practical students follow given instructions to obtain an outcome known by the lecturers. Expository activities can be followed by large numbers of students at the same time, with little set up in terms of putting the experiment together and running costs[2]. As the procedure is given, students may follow it without understanding the procedure[4] but due to its recipe-style formula, students can concentrate on learning basic experimental technique without getting distracted by detail limiting the strain on working memory[6]. This makes it ideal for large first year classes who need to build experience and confidence.

Inquiry
Inquiry or experimental practicals involve students generating their own methods and procedures. The outcome is unknown and students must come to a conclusion based on their work. With this approach students are responsible for the direction they take. For this type of activity it is important that the students are prepared or they may not reach the desired conclusion[7]. They need appropriate background knowledge which they can build on[8]. It places greater emphasis on the scientific process, rather than science content, which may lead it to being criticised as the amount of science content a student can cover will be reduced[9].

Inquiry activities closely mimic real research and give students ownership of their work and findings[2]. It is difficult to implement with large numbers of students, and requires much greater supervision as students are following their own plans. It relies on students having background knowledge and competent practical skills and also requires the student to process a lot of information. Therefore it may be more suitable for small numbers of final year students who have the required experience.

Discovery
In discovery practicals, students are given some background information and must develop their own experiments. Students are guided towards discovering the known outcome. The aim is for students to discover a concept for themselves and focuses more on interpretation of results, rather than experimental design as is seen with inquiry[2]. Again it is more time consuming as careful guidance is needed to ensure students reach the desired outcome. There are also arguments that student are unable to achieve outcomes if they are not known to them[3].

Problem based learning
Problem Based Learning (PBL) practicals involve students working in groups to solve real-life problems. They are given the problem, must find background information and procedures, and generate their own experiments. These types are usually put in a real life context to give more relevance[2]. Students are reported to have greater engagement with this type of practical work and appreciate being able to learn from their mistakes[10]. This is also time consuming to set up and needs close supervision as students can chose their own direction[5]. Within this, students use existing knowledge in a new situation, so this is not useful for adding to a student's knowledge base but allows students to show their ability to apply understanding.

Objectives of practical work
There has been much discussion in the literature about the objectives of practical work. Kirschner and Meester reviewed literature on practical work to try to define the overall objectives[11]. They found 120 different objectives, which they classified into eight general objectives:

- To formulate hypotheses
- To solve problems
- To use knowledge and skills in unfamiliar situations
- To design simple experiments to test hypotheses
- To use laboratory skills in performing experiments
- To interpret experimental data
- To design clearly the experiment
- To remember the central idea of an experiment over a significant long period of time

Carnduff and Reid outlined three broad areas for the inclusion of practical work[12]:

- Practical skills
- Transferrable skills
- Intellectual stimulation

Reid and Shah build on this by stating thirteen reasons for including practical work[13]:
Illustrating key concepts

- Seeing things for 'real'
- Introducing equipment
- Training in specific practical skills and safety
- Teaching experimental design
- Developing observational skills
- Developing deduction and interpretation skills
- Developing team working skills
- Showing how theory arises from experimentation
- Reporting, presenting, data analysis and discussion
- Developing time management skills
- Enhancing motivation and building confidence
- Developing problem solving skills

From these three examples of the aims of practical work, some themes recur. It is clear practical work is seen to develop chemistry practical skills. It also is seen to illustrate learning elsewhere and develop a range of transferable skills. What is not discussed is how students view practical work and if they actually achieve the aims set for the practical work. There is evidence to suggest that practical work does not achieve the learning expected[4]. Therefore it is important that whatever the aims of practical work are, suitable teaching methods are employed to ensure these are achieved.

Perceptions of practical work
Hanif *et al.* carried out a study of the views of practical work used in undergraduate physics courses to identify if practical work provides the desired outcomes and so is worth the costs involved[14]. 143 undergraduate students, mainly in the first year, with a small number form the second and third years,

were surveyed. The students were studying at a Scottish university, so those in the first year may be taking physics as part of a degree in another subject. The survey asked students about their experiences in laboratory work in physics through a series of statements with which they indicated their level of agreement, on a five point likert scale. Students overwhelmingly were found to prefer to have written instructions (76% agreement), and a large proportion (47%) agreed that they followed instructions without understanding what they were doing, this was supported by students agreeing that they only understood what they were doing when writing up afterwards (26% agreeing and 36% unsure). They saw the educational benefits of practical work, with agreement that the experiment linked to theory and that discussion in the laboratory enhances their understanding of physics. Students identified physics as a practical subject and placed importance on this being why practical work is included. They also identified using practical work to illustrate theories and for development of practical skills as being important. This research has looked at whether students in chemistry have similar opinions.

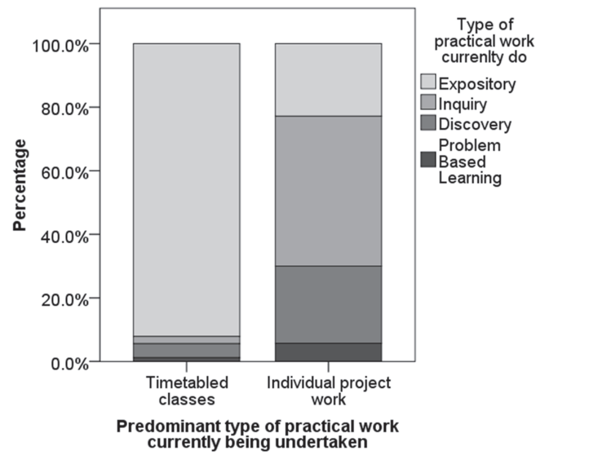

Figure 1: Type of practical work students currently do according to the scheduling of practical work currently being undertaken

Kirschner and Meester used a survey comprising of 63 learning objectives of practical work[15] as compiled by Kirschner and Meester[11]. Students in the natural sciences were asked to indicate before a practical activity if they expected to encounter each of these objectives in the practical activity. After the practical activity, they were asked to indicate from the same list of objectives, which they encountered. It was found that student expectations of practical work influences what they encounter regardless of what the intended objectives were. They found that if students are not aware of an intended objective then they will not achieve the set objective. Also students will encounter objectives they expect will be present, even if they are not present in the practical work. Therefore if staff and students have different opinions of the objectives of practical work, students may not achieve the objectives defined by staff.

Methodology

Two complimentary surveys were designed and distributed in early 2010 to collect staff and student's opinions of practical work; one for students currently studying for a degree in chemistry and the other for staff involved in the delivery of these courses. Nine English universities with known contacts were identified and the surveys sent via email, as a link to an online version on Bristol Online Surveys (BOS). These contacts were asked to distribute the staff and student surveys to others in the department. The universities targeted were a mixture of Russell group, 1994 group and other types of university, three of each type being selected. The surveys were also distributed via email lists to widen the sample.

The surveys were designed to build upon the literature. Belt concentrated on asking members of staff in chemistry departments to list their top three reasons for including practical work in chemistry courses[16]. Belt asked staff members in a variety of chemistry departments to list the purposes of practical work and he matched these to the 13 reasons listed by Reid and Shah[13]. A similar question was included.

Questions were also included based on the work of Sneddon *et al.* who asked undergraduates in physics about their perceptions and opinions of practical work[17]. Student respondents were asked to identify the type of practical work they carry out and which they would prefer to be carrying out based on Domin's four identified types; expository, inquiry, problem-based and discovery[3]. Staff were asked a similar question to identify which type they think students should be following.

Respondents were asked to identify the top three reasons they think are the most important for including practical work from a supplied list, comprising the 13 reasons identified by Carnduff and Reid[12] and discussed by Reid and Shah[13].

Overview of data

The percentage response rate from students from each of the nine targeted universities varies from 1 to 21% with the average being 10%. There is a wide range of responses from students from different universities and in different academic years; the data may be unrepresentative of the wider population so any analysis must be treated with care.

A total of 528 student responses were obtained from English universities. The responses represent 12 different universities, mainly Russell group universities (446 responses), and some from non-Russell group universities (82 responses). There is a small majority of respondents studying for an MChem (58%). The responses are from an almost 50:50 split of males (50.5%) and females (49.5%). This is consistent with national data which shows in 2005/6 the proportion of males to females entering chemistry courses was 56:44[1]. The majority of the responses are from students between the ages of 18 and 21 (89.3%). The majority (56%) of student respondents plan to follow a career directly related to chemistry, with 11% not planning to follow a career related to chemistry, and 33%, have not yet decided their career plans.

Only 46 responses were obtained from members of staff in English universities, representing 22 different universities. Of these, seven of the universities correspond to the universities represented by the student responses. This is a wide range, with only a few responses from each of the universities. The responses comprise 17 (37%) from Russell group universities, and 29 (63%) from non-Russell group universities. These are very small numbers of responses so analysis will simply be descriptive, and not statistically significant of the wider population.

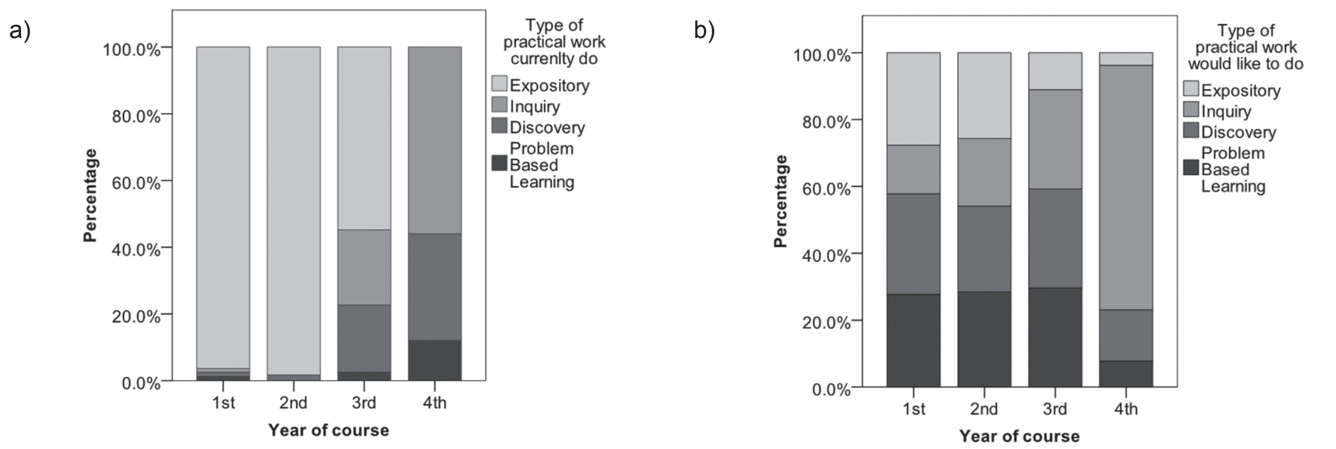

Figure 2: Type of practical work students a) currently do and b) would like to do, according to year of study

31 of the staff respondents (68.9%) are male and 14 (30.4%) female. This gender distribution is a little higher towards number of female respondents compared to the actual distribution found in chemistry departments in 2008, 80% male, 20% female[1]. The job titles given by the respondents cover the full range of job choices given in the survey, with the greatest number of responses being from senior or principal lectures.

Types of practical work carried out

On the surveys staff and students were given definitions for different types of practical work based on the four types Domin suggested are present in practical work (expository, inquiry, discovery, problem base learning)[3]. Student respondents were asked to identify what type of practical work they currently undertake and which they would like to carry out if they had the choice. Those students who are currently undertaking timetabled practical classes are predominately following expository procedures (Figure 1). This is traditional recipe style practical work that is widely carried out in undergraduate chemistry courses[2]. A small number of students identified the practical work currently being carried out as one of the other types. It is possible that these students mis-interpreted the definition or the question, but this is not clear and is a limitation of the survey data.

Those carrying out individual project work identified a range of types of practical work being followed (Figure 1). The predominant type followed is inquiry (47%) which describes a research project in which students devise and carry out their own experiments. 24% of students carry out discovery type of practical work. However, 23% of those students carrying out an individual project identify the type carried out as expository. This is unexpected as this would imply the students are carrying out experiments given to them to determine an outcome known to the lecturer. This type would not be normally expected to be associated with project work and could be due to the respondents misreading or misunderstanding the question, or perhaps is their interpretation of the practical work carried out.

Student respondents indicated that the majority of practical work carried out in years 1 and 2 is expository (96% and 98% respectively) (Figure 2a). This suggests that for the first two years of study, a recipe style of practical work is relied upon. Staff respondents support this, as they state it is the only type carried out in the first year and the predominant type in the second year. Staff indicate that if they could change the type of practical work followed, the majority would chose expository for first year students. This type is easy to run with a large number of students as all students will be following the same experiment[2]. It is also perhaps easier for students with little practical experience to follow so would make sense for this to predominate[5].

A study by Meester and Maskill analysed the content of first year chemistry practical manuals from 17 universities in England and Wales to determine the level of scientific inquiry covered[18]. They found that over 90% of the experiments analysed covered a low level of scientific inquiry, in which the

Table 2: Type of practical work indicated by staff being predominately carried in each year of study

	1st		2nd		3rd		4th	
	No.	%	No.	%	No.	%	No.	%
Expository	45	100	39	86.7	14	31.8	1	2.6
Inquiry	0	0	4	8.9	15	34.1	21	53.8
Discovery	0	0	1	2.2	14	31.8	13	33.3
Problem Based Learning	0	0	1	2.2	1	2.3	4	10.3
No. Responses	45		45		44		39	

aims and methods are given to the student, in other works they follow an expository method. It would appear that not much has changed since this study in 1995, with 96% of first year students still following expository type practical work.

Students in the third year of study indicated a greater range of practical types being followed (Figure 2a), with expository still being the predominant type (55%), so the majority of students are still carrying out traditional types of practical work. In the third year, 23% of students undertake inquiry, 20% discovery and 3% problem based. Some third year students, both MChem and BSc may be undertaking project type work which would support a range of types of practical work[1]. Staff respondents confirm that practical work in the third year is more varied (Table 2), with a roughly even split of expository, inquiry and discovery.

By the fourth year of study, students who responded indicate that expository based practical work is no longer undertaken (Figure 2a), which is confirmed by staff (Table 2). The predominant type now is inquiry (56% student response; 54% staff response) followed by discovery (32% student response; 33% staff response) and problem based (12% student response; 10% staff response). Students in the fourth year are those following a MChem programme and these students would be expected to carry out an extended project. From these responses these projects appear to cover a range of types, which all involve development of their own experiments. This indicates that by the fourth year, students have more freedom with the practical work they undertake.

Overall students indicated that the type of practical work they would like to carry out (Figure 2b) is quite different from what they currently carry out (Figure 2a). Students want to carry out less expository based practical work, with only 28% of first year students wishing to carry this out, compared to 96% who currently carry it out. The amount of students wishing to carry out expository practical work decreases with year, with 26% of second years, 11% of third years and 4% of fourth years.

By the fourth year, the majority of students would like to carry out inquiry based practical work (73%) which involves carrying out a research based project. This suggests that as students progress through the years they appreciate carrying out different types of practical work, perhaps as they gain more experience in basic techniques.

Staff also indicate that there should be less reliance on expository types of practical work in later years, with greater emphasis on inquiry and problem based. Due to the limitations of the data, it is not clear why this is so. These alternative types develop a wider range of skills and challenge students more[19]. Perhaps staff feel this is important for the development of the students. Inquiry and problem based are also more akin to the scientific process[2], and encourage students to connect new knowledge to old[7] which may be seen as an important aspect of practical work.

Objectives and outcomes of practical work
Both staff and students were asked to select the three most important reasons for including practical work into the chemistry course from a list of 13 (Table 3).

*Table 3 : The most important reasons selected by staff and student respondents for including practical work into the chemistry course. Student responses are also shown according to year of study. The top reason is highlighted in **bold**. The lowest rated reason is highlighted in italics*

	Percentage response					
	Staff	Students				
		Overall	1st	2nd	3rd	4th
	n=46	n=528	n=256	n=121	n=122	n=26
Developing deduction, interpretation skills	43.5	30.1	30.9	25.6	34.4	23.1
Developing observational skills	8.7	13.3	15.6	12.4	11.5	***3.8***
Developing problem solving skills	34.8	26.9	25.0	27.3	27.9	42.3
Developing team working skills	6.5	***7.0***	***9.8***	***5.0***	***4.1***	***3.8***
Developing time management skills	*4.3*	12.5	12.9	13.2	11.5	11.5
Enhancing motivation and building confidence	6.5	9.5	***9.8***	8.3	10.7	7.7
Illustrating key concepts	39.1	30.3	34.4	25.6	28.7	19.2
Introducing equipment	8.7	24.2	25.0	23.1	27.9	7.7
Reporting, presenting, data analysis and discussion	45.7	**41.3**	**36.7**	**44.6**	**46.7**	46.2
Seeing things for 'real'	26.1	24.2	26.2	26.4	19.7	15.4
Showing how theory arises from experimentation	17.4	34.7	36.3	38.8	28.7	23.1
Teaching experimental design	13.0	11.4	10.2	12.4	12.3	15.4
Training in specific practical skills/safety	**50.0**	32.0	26.2	29.8	40.2	**61.5**
To achieve Royal Society of Chemistry Accreditation	***4.3***	-	-	-	-	-

Only 46 staff responses were collected so the data may not be truly representative of staff views. Overall both staff and students have identified similar reasons for including practical work in chemistry courses. This implies that students have the same ideas about why practical work is included and perhaps are aware of the aims of practical work which staff intend them to achieve.

Within the student and staff surveys, the respondents were presented with a list of statements about how students experience practical work and what staff think students take from practical work, and asked to rate the statements on a five point likert scale. The agree and strongly agree, and disagree and strongly disagree responses have been combined to indicate those who responded positively to a statement and those who responded negatively, to give a simpler overview of the data (Table 4). Overall, the staff opinions about the student experience of practical work are very similar to those of the student respondents.

Reasons for including practical work

Both staff and students identify developing practical skills and scientific skills as the most important reasons for including practical work. *'Training in specific practical skills/safety'* was identified as the most important reason by staff, with 50% of the respondents choosing this (Table 3). Clearly, staff see practical work as being very important to developing practical skills, perhaps for students to be trained as future researchers or for their future careers[4]. 32% of student respondents identified this reason (third most chosen reason). Within practical work, students will use a variety of techniques throughout the course, so clearly they see this as an important aspect of practical work[2]. Students and staff reported that practical work skills are indeed developed (Table 4).

Training in specific practical skills/safety is identified as one of the top reasons by second, third and fourth year students (Table 3). However, first year students do not identify this as one of the top three reasons. Instead they identify illustrating key concepts as the third most important reason (34%), which is not identified by the other three years as one of the top three reasons. This perhaps suggests that first year students expect practical work to be used to illustrate chemistry covered elsewhere in the curriculum, and as the students progress through the years, they see this as a less important aspect of practical work. Practical work is often not linked to lectures leading to it being seen as isolated and unrelated[11].

Students reported that practical work develops a range of scientific and practical skills; including observational skills (82% agreement), and interpretation skills (72% disagree with the statement 'I do not develop interpretation skills during practical work'). The predominant type of assessment for practical work is writing up an experimental report[2]. Staff and students both recognise this as an important aspect of practical work. *'Reporting, presenting, data analysis and discussion'* was identified highly by staff (second reason, 46%) and as the most important by the student respondents (41%) (Table 3).

Table 4: Comparison of staff and student responses about the student experience of practical work. The statements have been modified to allow comparison of the staff and students responses

	Staff, n=46			Student, n=546		
	SA/A	N	D/SD	SA/A	N	D/SD
Helps learn	87.0	13.0	0.0	82.1	11.5	6.4
Illustrates key concepts	93.5	6.5	0.0	81.0	13.6	5.5
Rely on written instructions	75.6	20.0	4.4	43.0	24.5	32.4
Observational skills developed	76.1	19.6	4.3	82.2	14.3	3.5
Opportunities to write reports	97.8	2.2	0.0	80.2	10.6	9.2
No chance to work in teams	17.4	17.4	65.2	19.8	17.4	62.8
Time management skills developed	60.9	28.3	10.9	73.4	17.1	9.5
Increases motivation	67.4	28.3	4.3	59.9	25.0	15.1
Helps see things for 'real'	82.6	17.4	0.0	80.0	14.9	5.1
No opportunity to design experiments	56.5	23.9	19.6	68.4	14.7	16.9
Gain practical skills	100.0	0.0	0.0	98.2	1.7	0.2
Helps understanding of chemistry	93.5	4.3	2.2	78.7	12.9	8.3
Develop interpretation skills	87.0	8.7	4.3	71.5	19.8	8.7
Chance to problem solve	73.9	19.6	6.5	72.9	16.6	10.5
Prefer full instructions	84.8	13.0	2.2	57.8	28.0	14.2
Does not illustrate how theory arises	19.6	28.3	52.2	16.1	22.0	61.9
Essential part of chemistry	100.0	0.0	0.0	93.7	3.5	2.8
Help support lectures	82.6	13.0	4.3	78.5	12.1	9.4

The third reason identified by staff, *developing deduction, interpretation skills*, as seen was less important by students (Table 3). Staff clearly think that practical work should develop deduction and interpretation skills, but perhaps there is not enough emphasis that students should be developing these skills or perhaps are not aware that they are developing these skills.

'Teaching experimental design' was not identified as one of the top three reasons by staff or students (Table 3) and also was not identified as being developed (68% of students agree with the statement 'I don't get the opportunity to design experiments' (Table 4). Students identified that the predominant type of practical work carried out in the first three years is expository (Figure 2a). This involves carrying out experiments in a recipe approach, with no room for a student to diverge from the set method. It is not surprising therefore that students do not identify teaching experimental design as a key reason for including practical work in the course. It is unlikely they will come across experimental design until the third or fourth year in which they begin to undergo a greater amount of inquiry and discovery type of practical work (Figure 2a) in which experimental design will be used to plan their own experiments.

As students progress through their course, they are more likely to get the chance to design experiments within practical work, with 77% of first year's, 77% of second year's, 52% of third year's and 37% of fourth year's agreeing that they do not get the opportunity to design experiments. This would fit with the change in the type of practical work predominately carried out by students in different years (Figure 2a), with first year's predominately carrying out expository which involves simply following a set procedure, and fourth year's carrying out inquiry type of practical work more predominantly which will give students a chance to design their own experiments.

Practical work for developing transferable skills
Practical work can be used to develop transferable skills[4]. However, in this study, neither staff nor students rated developing these skills particularly highly. *'Developing team working skills'*, '*developing time management skills'* appear within the lowest three reasons identified by both staff and students. Students do identify that practical work does develop these skills (Table 4; 63% disagree with the statement *'I do not get the chance to work in a team during practical work'*). The QAA and RSC highlight the importance of the development of transferrable skills, but this reveals staff do not believe this is an important reason for including practical work.

More staff think that practical work helps illustrate key concepts, 94% compared to 81% of students, suggesting students are not aware of this and are perhaps not making the link.

Students believe their time management skills are developed to a greater extent than staff believe they are (73% agreement compared to 61% of staff; Table 4). Staff believe that interpretation skills of students are developed (87% agreement), and fewer student believe this (72%). This could imply that students are not aware of these skills being developed.

There is also agreement that practical work helps develop team working skills, (65% of staff disagree with the statement '*Students do not get the chance to work in a team during practical work'* and 63% of students disagree; Table 4).

'Developing problem solving skills' was chosen as one of the top three reasons by a higher number of both staff (35%) and students (27%) (Table 3). Interestingly, fourth year students rate developing problem solving skills as the third most important reason for including practical work (42%).

Practical work for supporting learning
There is mixed response to the inclusion of practical work being to support learning. Staff rated *'Showing how theory arises from experimentation'* seventh, compared to students rating this as second, and '*Illustrating key concepts'* was given the same rating, fourth most important by both (Table 3). *'Seeing things for 'real''* was also chosen in the top three reasons by a similar number of staff (26%) and students (24%). Both groups see practical work as contributing to some extent to supporting learning gained elsewhere.

Both staff and students did agree that in reality practical work helps support learning. Students agreed that practical work helps them to learn more chemistry (82%) and helps understanding of chemistry (79%), and staff also agreed that practical work helps students to learn more chemistry (87%; Table 4). Staff and students both agree to a similar extent that practical work helps support lectures, 83% of staff agree and 79% of students agree. This suggests staff expect practical work to help support lectures, and students are indeed experiencing this.

More staff think that practical work helps illustrate key concepts, 94% compared to 81% of students (Table 4), suggesting students are not aware of this and are perhaps not making the link. This may be due to issues of course structure, as practical work may not be able to be scheduled to relate to appropriate lectures, leading to practical work being seen as isolated exercises[11]. Staff also have a greater agreement that practical work helps students to understand chemistry, 94% compared to only 79% of students agreeing with this. This suggests that students are not taking away as much from practical work as staff think they are with regards to learning chemistry. This would support the idea there is little evidence to suggest practical work adds to student learning[20].

Practical work for accreditation

The least important reason identified by staff, *to achieve Royal Society of Chemistry accreditation* (Table 3), was not given as an option to students as they are not involved in accreditation. It is clear staff do not think this is a particularly valid reason for including practical work, even though the majority of chemistry courses in England are accredited[1].

Experience of practical work

The majority of student respondents (71%) feel confident carrying out practical work (Table 4) suggesting that they acquire the appropriate skills needed to carry out the experiments and also that they get any support required. This confidence appears to be greater for student respondents in higher years, with 65% of first year, 75% of second year, 72% of third year and 91% of fourth year students agreeing. This would indicate that students improve their practical skills and hence confidence as they progress.

The majority of students indicated they prefer to have full written instructions for practical work (58%) with only a small amount (14%) disagreeing with this (Table 4). Sneddon *et al.,* reported that the first year physics students surveyed preferred to have written instructions[17]. This is supported by the type of practical work students are currently undertaking, dominated by expository in which written instructions will be provided (Figure 2a). However, when asked what practical work students would like to do, they favoured the other types of practical work (Figure 2b) which would not necessary rely on instructions, but give students more freedom to follow their own experiments. This does not support students indicating they prefer written instructions, so perhaps they are more comfortable with what they are used to.

Both staff and students emphasised the use of practical work to develop scientific skills, with less emphasis on its use to support learning of chemistry.

85% of staff believe students prefer to have full instructions, but only 58% of students agree with this. Student respondents in higher years indicate less of a preference for full written instructions. This could be due to students' experience of different types of practical work. By the fourth year the majority of students are undergoing research projects (Figure 2a), which will not have instructions and so they have more experience of not having written instructions and perhaps see a benefit and preference for not receiving full instructions.

Staff believe that students rely on written instructions without fully understanding the procedure to a much greater extent than students claim they do, 76% of staff agree compare to only 43% of students (Table 4). Sneddon *et al* reported similar findings, in which the physics students surveyed stated they did not reply on instructions without understanding the procedure[17]. This suggests either students are engaging with practical work to a greater extent than staff think they are, or that students believe they are engaging with the work and not relying on written instructions. There is evidence in the literature to suggest students do indeed follow instructions without understanding[4]. This seems to be what staff are experiencing and may be a downfall of the type of practical work being followed, for example expository which allows students to simply follow instructions. By the fourth year, students appear to rely less on full written instructions with only 26% indicating they rely on following written instructions without fully understanding the procedure. This would indicate that as students become more confident with their practical skills and have more experience, they are able to engage more with the practical work being carried out, giving progression in skills development[4].

There is strong agreement that staff and students see practical work as being essential to the chemistry course (Table 4). They both clearly see practical work as being useful for developing a wide range of skills as well as supporting learning elsewhere in the chemistry curricula. This may be supported by the fact that the majority of students feel practical work will be useful to their future careers (70%). The majority also indicate that practical work increases their motivation to study chemistry (60%). This motivation is more likely to be identified by students in higher years, with 71% of fourth year students and only 52% of first year students agreeing that practical work increases their motivation to study chemistry. First year students identify expository as the main type of practical work being followed (Figure 2a) whereas fourth year students are more likely to be carrying out a research style project, so perhaps this increases their motivation to study chemistry as it is more aligned with real chemistry experiments[19]. Perhaps as the main activities carried out are expository, which simply verify something already known to the student, motivation is reduced as suggested by Kirschner and Meester[11].

Conclusions

There are a wide ranging number of objectives that may be present in practical work[11,12,13]. These all cover three general areas of developing practical and scientific skills, developing transferable skills and supporting learning. This research found that staff and students have similar ideas about why practical work is included, and feel that students are achieving these aims. It is clear that both staff and students see the benefits of practical work in terms of skills developed. The most common reason given is to develop practical skills. Both staff and students emphasised the use of practical work to develop scientific skills, with less emphasis on its use to support learning of chemistry. Students are more likely to identify the use of practical work to promote learning elsewhere. What is still not clear is if students do actually learn anything from practical work or it simply develops both scientific and transferable skills.

This work has built on previous work to examine the types of practical work currently being carried out in undergraduate chemistry courses in England. Meester and Maskill found that expository types of practical work dominated in chemistry first year practicals[18]. This research shows this is still the case, 15 years on. Expository is seen as limited in its ability to develop students into scientists as it encourage them to simply follow instructions without thinking and encourage passive learning[10]. These are cheap and easy to run with large numbers of students[2]. It is easy to see why universities rely on these methods when the financial climate is increasingly uncertain. It is important that it is clear what the objectives of practical work are and the appropriate method is used to reach these objects. This research found that staff agree that this is a more desirable method for first year students, perhaps as it allows them to gain experience in basic techniques without getting confused by other details[5].

Inquiry based activities seem to be well established in the final years of practical work, which commonly involve an extensive open ended investigation[1] and this research has confirmed this. There is little evidence to suggest this type is used in lower years of a course. Staff appear to believe this type should be introduced earlier in the course, perhaps to allow student to develop skills progressively[2].

Problem based activities do seem to be growing in popularity, with an increasing number of examples being found in the literature[5,10,19]. This type has been shown to have educational benefits such as motivating students and problem solving, as well as helping student understand concepts[6]. It also builds on students prior knowledge so helps them to make connections to other learning.

It would appear that different styles of practical work will suit learners at different stages of development. Each type has advantages and disadvantages and can be used to achieve different outcomes. There is some debate about the true objectives of practical work, but staff and students do appreciate its importance in the curriculum. Whatever the objectives are deemed to be, they must be made clear to the student to ensure they can achieve them, and a suitable pedagogic method must be employed.

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