Embedding Pedagogy in Practical Science

Funded through the LSIS STEM Programme

LSIS LEARNING AND SKILLS IMPROVEMENT SERVICE

Teaching and learning

Embedding Pedagogy in Practical Science

I am delighted to be able to introduce this innovative and stimulating report: "Embedding Pedagogy in Practical Science", developed by the Learning and Skills Improvement Service (LSIS) as part of the Teaching and Learning Programme.

This Programme aims to support providers to improve the quality of teaching and learning by linking organisational strategies for quality improvement, continuing professional development (CPD) and the Subject Learning Coach model. The emphasis is on helping the sector help itself, knowledge transfer and building on what is already there.

Teachers, tutors and trainers in the learning and skills sector work with a wide range of learners – work-based learning organisations, in adult learning, in colleges, in prisons, in voluntary and community organisations and in the workplace. This resource has been developed in consultation with them and their learners as well as other subject and national experts. The resource has also been designed to support the aims of the Institute for Learning (IfL) and the requirements for Professional. As the professional body for teachers, trainers and assessors across the learning and skills sector, IfL's key priority is to support individual teachers' and trainers' learning so that they can maintain their high professional status and have long-term CPD interests as career teachers.

I hope you find this resource and the approaches of real benefit to you and your organisation. I am certain you will find it provides an excellent opportunity for your teachers, tutors, trainers and managers to improve their professional development and support LSIS's mission of excellence for the learning and skills sector as a whole.

Markos Tiris
Programme Director Teaching and Learning

The research programme's aim was to support and disseminate effective practical work in further education science classrooms.

Executive summary

This report summarises the key findings from twenty-one action research projects carried out to embed pedagogy in practical science in fourteen further education colleges April to July 2009. The research programme's aim was to support and disseminate effective practical work in further education science classrooms, in line with LSIS's Teaching and Learning Programme's (TLP) aims and objectives.

The premise for this project has been that effective practical work requires ideas as well as equipment to be manipulated in the laboratory. The project drew upon the ten effective pedagogies used in the TLP's 'Talking teaching, training and learning' pack, illustrating their relevance to practical science.

16 of the 21 project leaders have found that the project has already made an impact on their practice and learners, and the other five expect there to be an impact once data collection and analysis has been completed.

A key lesson learned from this programme is that understanding learners' and colleagues' attitudes towards different pedagogies in practical work significantly aids in developing lessons that are more engaging and motivating as well as developing knowledge and understanding effectively.

Most of the projects developed new or different practical experiences for learners to improve learning of particular topics in their subject. Where appropriate for wider dissemination, these have been included with the project reports.

Improvements to knowledge and understanding as well as to motivation and interest have been achieved by:

- introducing independent practical work opportunities
- the use of modelling
- Socratic questioning and the development of worksheets, starters and plenaries and better instructions for practicals have helped to forge better links for learners between practice, theory and applications.

Alternative methods for assessing practical work using photo-editing software, verbal presentations and worksheets have also been developed and tested.

Practical work has been used as a focus for increasing retention between AS and A2 and for encouraging recruitment to science courses from partner schools.

Feedback from participating teachers and lecturers indicates that action research is a motivating and effective form of continuing professional development (CPD) because the research undertaken is relevant to local circumstance and situation. This leads to research results that vary in depth and breadth from institution to institution, and some are more widely applicable than others. In some cases, projects are still in progress and their full impacts will only be known once examinations have been taken. However, all those who participated have reflected upon and made changes to the pedagogies they use for practical work, and have created and shared resources regionally. Some are now conducting a thorough review of practical work in their colleges. All have disseminated their work to peers and beyond.

Project report

Background

The Science Community Representing Education (SCORE) recent report "Practical Science: a report and proposal for a strategic Framework" (2008) states that 'The importance of practical work in science is widely accepted and it is acknowledged that good quality practical work promotes the engagement and interest of learners as well as developing a range of skills, science knowledge and conceptual understanding.'

While learners in the UK spend more time on practical work than elsewhere, the report also indicates that there are growing concerns that the amount and quality of practical work have both suffered in recent years, with a chasm between what teachers and lecturers identify as their outcomes before lessons and the outcomes learners perceive.

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The premise for this project has been that effective practical work requires ideas as well as equipment to be manipulated in the laboratory. The project drew upon the ten effective pedagogies used in the TLP's 'Talking teaching, training and learning' pack, illustrating their relevance to practical science. These pedagogies are:

- Assessment for Learning
- Co-operative learning
- Differentiation
- Embedding literacy, language and numeracy
- Experiential learning
- Learning conversations
- Modelling
- Multi-sensory learning
- Relating theory and practice
- Using e-learning and technology.

Action research was chosen as the model for CPD. Teachers and lecturers plan action and implement changes to their practice in the classroom, and then research the impacts these actions effect by gathering evidence from learners.

"The most rewarding part of this process was when one of the adult learners said that it was the best lesson she had ever had!"

Feedback from participating teachers and lecturers indicates that action research is a motivating and effective way to fulfil CPD requirements. The Institute for Learning (IfL) guidelines also recommend carrying out and disseminating action research as an effective method of CPD. It embraces the needs for dual professionalism (subject focus along with teaching and learning practice) and reflective practice.

Project Structure

Three Science Learning Centres (East of England, North East and North West) recruited teachers and lecturers to participate in Spring 2009. Those who expressed an interest attended an initial, subject-specific CPD session in April 2009. This provided:

- a brief review of what current research says about pedagogies for effective practical work
- self-assessment of current pedagogies used in practical work and developing strategies to improve and extend learning outcomes
- exploration of web-based resources to support practical teaching and in particular the Practical Chemistry, Physics and Biology websites
- an introduction to the principles for this action research: to identify effective pedagogies; reflect on own and collective practice; listen to learners' voices; develop and implement improved practice; identify and address influential factors through reflection; share results with colleagues; and plan for future improvements
- time to plan how to improve the quality of practical work through action research
- opportunities to meet and share ideas with colleagues.

As several people who attended the initial CPD were not able to carry out the project, the invitation to join the programme was extended to all regions which resulted in participation from colleges in London and the South West.

All participating teachers submitted a research action plan and carried out their research over two months. They were supported by mentors from each of the Science Learning Centres. Final reports were completed by the 17th July and results were disseminated through regional twilight events and by sharing short videos between researchers.

"I was aware that our practical lessons could be improved but now I feel that I have the confidence and skills to make those improvements happen."

In total, 21 projects were awarded to 14 colleges. These are listed overleaf.

Project no.	Region	Lead organisation	Project title
1	North East	East Durham College	Embedding Pedagogy into Practical Procedures. Specifically in the practical: The Effect of Temperature on Enzyme Activity
2	North East	Newcastle Sixth Form College	Modelling meiosis to improve learning and motivation
3	North East	New College, Durham	Teaching pedagogies in practical science - understanding learners' perceptions to redesign chemistry practical work
4	London	St Dominic's Sixth Form College	Investigating how practical work can be used effectively to develop subject knowledge and understanding, and improve learner enjoyment
5	South West	Strode College	Improving practical skills through independent projects
6	South West	Strode College	Bridging GCSE and A Level Biology: using practical work to improve progression
7	South West	Strode College	Experimental investigation of reaction kinetics: does independent project work make a difference?
8	East of England	North Hertfordshire College	Investigating the use of practical templates to aid learners in the understanding of practical procedures
9	East of England	Chelmsford College	Assessing practical work using verbal presentations
10	East of England	Paston College	'Does a formal practical sheet aid learning through practical work?'
11	East of England	Cambridge Regional College	Teaching Scientific Applications before theory: the impact on learners
12	North West	Loreto College	Investigation of rates of Photosynthesis at different wavelengths of light and or with different concentrations of chloroplasts: using practical work to improve learning
13	North West	Loreto College	Improving enzyme experiments to improve learning
14	North West	Loreto College	Fermenter experiments to improve maths, datalogging and self-start projects
15	North West	Aquinas College	Using video/web-cams in Physics to analyse motion
16	North West	Nelson & Colne College	Starchaser Propulsion Day
17	North West	Nelson & Colne College	Rockets practical and worksheets
18	North West	Stockport College	Crime scene processing
19	North West	Stockport College	Developing Practical Skills: learners using photo-editing software to create instructions
20	North West	Wirral Metropolitan College	Making Biology More Relevant
21	North West	Wirral Metropolitan College	Investigating Methods of Instruction in Practical Skills: Visual instructions for titrations

"Some of the experiments we were shown were inspirational, a reminder of why we find science fascinating."

Impact levels

Project leaders were asked to assess the level of impact of their action research (none, a little, substantial or major). All those who had completed their actions stated that the project had little or substantial impact. Project leaders annotated the form in some case and the full results are:

Level of impact	Number of projects
No impact	0
A little impact	5
A little impact with more expected	1
Substantial impact	10
Substantial impact expected	1
Major	0
To be confirmed when results are confirmed in the autumn	4

Note that in six cases, the final data required to assess impact could only be obtained when learners return in September.

Impact on learners

The projects reported a wide range of impacts on learners.

A key lesson learned from this programme is that understanding learners' (and other teachers' in the departments') attitudes towards different pedagogies in practical work significantly aids in developing lessons that are more engaging and motivating as well as developing knowledge and understanding effectively.

At the beginning of the project, teachers and lecturers carried out a self-evaluation of their use of different pedagogies in practical science. This was based on the SCORE research described above and the TLP's 'Talking teaching, training and learning' pedagogies. Many then carried out similar questionnaires with their learners before redesigning existing or developing new practical experiences, and then questioned learners again after the lesson or module had finished. The process of engaging learners in itself also proved valuable, enabling the learners to consider their own learning practice and preferences.

Projects demonstrated improved knowledge and understanding using test results or combinations of test results and Value Added Scores. Knowledge and understanding were also assessed and shown to have improved through practical write-ups, worksheets, learner presentations and observations. In addition, projects also encouraged cooperative learning to improve interpersonal and communication skills and

developed active learning and problem solving to improve higher level thinking skills.

Many of the projects found that the changes they made had a positive impact on learner motivation, confidence and interest. Evidence for this was captured using questionnaires, focus groups, and discussions. In several cases, projects reported an increase in attendance. Increases in intended retention in progression from AS to A2 (as compared to intended progression recorded at the same time in previous years i.e. in July) were also noted.

Project leaders will be assessing the impact these projects have made on attainment by monitoring examination grades.

Many projects developed new or different practical experiences

for learners to improve learning of particular topics in biology, chemistry, physics, applied science, forensics and health studies, for example, introducing modelling or independent practical work. Projects also implemented new tools to develop and assess understanding as well as practical skills. Key findings were:

1. Incorporating hands on modelling sessions can help improve motivation and improve understanding of concepts as well as being a useful revision aid;
2. Opportunities for extended, independent research can improve motivation and interest in the subject, as evidenced by increased attendance and engagement in the task;
3. Links between practice and theory can be improved by using Socratic questioning before carrying out a practical and can improve confidence and understanding in practical work;
4. By developing pictorial instructions for practicals, more emphasis can be given to understanding the underlying concepts than how to carry out the practical work itself;
5. Links between practice and theory can also be improved using starter and plenary activities: for example, 'Learners feel they understand better if they are told what is going to happen and then they look for it rather than encouraging finding out style lessons. This is certainly something to use in future';
6. In one project, the use of gapped worksheets helped learning in practical work, resulting in more discussion with lower achieving learners in particular. The sheets also helped if learners missed a session and provided a good way of assessing practical work. 'Before practical activities, time was set aside for learners to gain understanding of practical procedures to help improve learning and participation in practical work. This was done by providing learners with a structured worksheet with each step of the

practical procedure broken down. Gapped sections were provided which required learners to describe why they were doing at each step and what was happening';

7. Knowledge and understanding can be demonstrated and assessed effectively through verbal presentations and by creating photographic instructions for practicals instead of producing written reports. In one project, the use of pictures in instructions made a big difference to learning:

"The learners who followed the photographic instructions generally:

- carried out the titration more independently, they asked fewer questions in order to progress with the method
- reported that they needed less help
- reported that they found the instructions easy to follow, clear and helpful"

"The learners who followed the written instructions generally:

- carried out the titration less independently, they asked a lot more questions in order to progress with the method.
- reported that they needed more help
- reported that they found the instructions unclear, confusing and difficult to follow."

Effective practical work in open days can help promote progression from school to further education.

Two projects focused on using inspiring practical work in open days to encourage more learners from schools to pursue science. Enquiries following an open day in physics rose by 34 %, for example. In addition, colleges have forged better links with their feeder schools as a result.

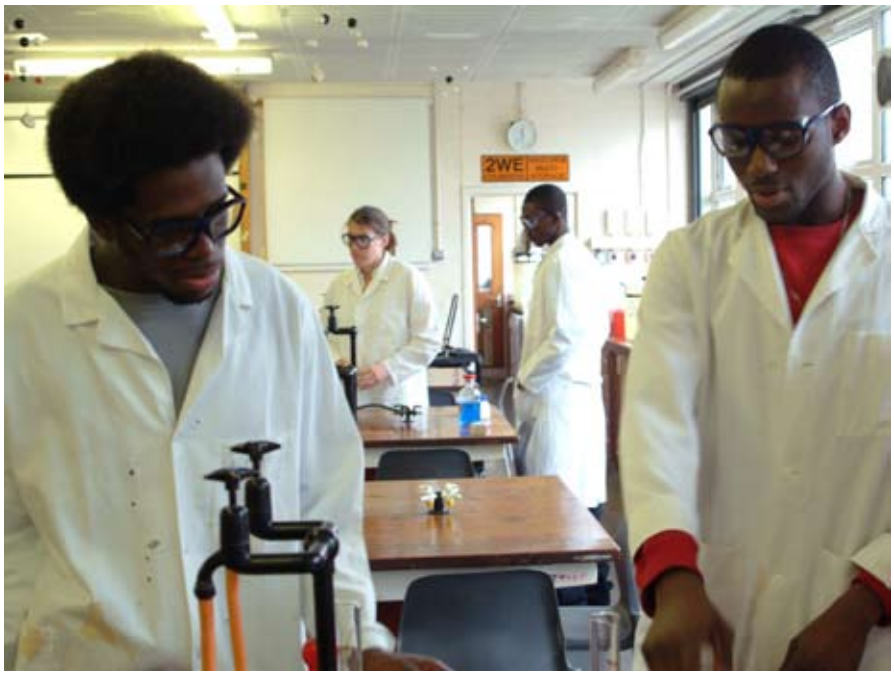
Impacts on teachers and lecturers

All project leaders responded positively to the impact action research has had on their practice, with all participants introducing either new practical activities or improving existing ones. It enabled a deeper understanding of the pedagogy of practical work and increased subject knowledge.

Participating in action research has increased motivation, for example: "The most rewarding part of this process was when one of the adult learners said that it was the best lesson she had ever had!" and "I was aware that our practical lessons could be improved but now I feel that I have the confidence and skills to make those improvements happen."

As well as resources for action research and practical work, guides for the whole department to use to improve practical work, and course booklets based on learner experience, have been produced as a result of the project, for example, "the response has been very positive from some learners so I have planned a practical booklet for AS and one for A2 which has formal questions in the text and has follow up questions to give learners an opportunity to reflect on their experience." Many of the researchers are continuing with their research, for example, "I will be following up the research when the new academic year begins as I'd like the same level of understanding and enjoyment in each of the practicals."

Some are reviewing and analysing further aspects of practical work in their courses. Many are involving others in their department to carry this out. All are sharing the results of their work within their departments and at network meetings. Some are sharing their results and resources more widely with other local colleges and beyond.
The participants valued the project's initial professional development workshop and workshops to share results:



"The initial meeting was very rewarding. First, it allowed us to discuss different teaching styles so it impacted on our effectiveness in the classroom. It allowed us to share learning activities we found worked with our particular learners. The leader of the session also shared ideas of how to achieve effective learning. Some of the experiments we were shown were inspirational and a reminder of why we find science fascinating."

"I was very inspired in the feedback meeting by the use of models to explain theory. This would be a very easy thing to set up as a pre-practical activity. I was also inspired by another participant who had had similar ideas to mine about including Socratic questions in the procedure."

"The opportunity to collaborate as part of a network to share teaching practice and develop resources for the learners' was also valued."

See 'Appendices' for a selection of reports and resources from the funded action research projects.

The LSIS STEM Programme

The LSIS STEM Programme offers unique support for the learning and skills sector, working with managers and teachers in all settings – colleges, work-based learning, prison units and adult education.
www.excellencegateway.org.uk/STEM

A consortium of leading organisations involved in STEM education are delivering the programme:

Science Learning Centres

The Royal Academy of Engineering

National Centre for Excellence in the Teaching of Mathematics