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"Sir, if we are doing all the work what is the point of you being here?": Using Problem Based Learning to enhance subject knowledge and academic intrinsic motivation in a Year Nine Physics class

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Abstract

The use of Problem Based Learning is well established as a pedagogical tool to improve wider skills in a variety of educational settings. Its use in UK secondary schools makes up only a small portion of the literature, with little understanding of its effect on motivation. This paper looks to measure Problem Based Learning on subject knowledge assimilation and individual academic intrinsic motivation, alongside interviews, observations and analysis of pupil's work. Results showed that skills such as teamwork, leadership and co-dependence can be developed at the expense of subject knowledge. Qualitative observations were positive to the use of Problem Based Learning in a vibrant KS4 class from an inner city British secondary school.

"Sir, if we are doing all the work what is the point of you being here?": Using Problem Based Learning to enhance subject knowledge and academic intrinsic motivation in a Year Nine Physics class

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Introduction

A consistent theme within educational discourse; in academia and in school based professional development, is the focus on how to make our pupil's better independent learners. The transition from a Lecture Based Learning (LBL) classroom, prevalent across education in the UK, to a PBL setting has seen a resurgence in attention. Whilst PBL has seen its popularity grow, there is little research measuring subject knowledge assimilation from PBL in a UK secondary school environment. Whilst intrinsic and extrinsic motivation of pupil's has substantial literature behind it only a small body of research has looked to observe the effect of PBL on motivation, with the bulk of this taking place in further education. The impact of utilising PBL in a KS4 class remains largely unclear with many years of LBL potentially creating an unconscious bias to pupils' expectations of a teacher's role. In this study, specific emphasis is placed on pupils' ownership of learning, communication and critical thinking. These inherent characteristics of PBL struggle to surface during LBL and would be encouraged and developed over a short series of lessons.

Utilising my own experience of independent learning, education literature and guidance from school-based research books, this study aimed to clarify some expectations of PBL in the classroom. The school-based population will be of top set year nine pupils' (n=30). Due to the setup with the school, year nine sees the start of the KS4 syllabus in science. This allows more time to be spent on each area of the syllabus but conversely means that recall needed for General Certificate of Secondary Education (GCSE) exams will be over two years. It is clear from this that ownership and motivation must be high to ensure pupils have the best chance of a meaningful learning journey in the lead up to their exams. PBL is viewed as novel in an LBL dominated environment. To ignore such an approach is to put many pupils at a disadvantage when you consider the prevalence of the need for such skills in University and the workplace.

PBL enhances a strong teacher-pupil relationship where freedom of expression and passion for learning is encouraged and developed. This assignment will argue that PBL is an effective tool to enhance wider skills in the classroom and as such should be utilised by teachers as early as possible in secondary education. Each section will outline data collection and results to answer specific research questions that have emerged from this action research. Measurements of pupil's subject knowledge acquisition and intrinsic motivation will be analysed alongside interviews, observations and interpretation of pupil's work. This small-scale research aimed to provide a pedagogical tool to enhance the science classroom for the teacher and pupil's alike.

Literature Review

Introduction

Within this literature review is a reasoned approach to establish the application of education research in the field of PBL. There is a focus on intrinsic motivation, particularly with regards to studying science as well as discussion of pupils' epistemological beliefs. Discussions in this area will examine the work of Mubeen and Reid (2014) whose work on intrinsic motivation in science has greatly influenced this study. The work of Mubeen and Reid (2014) focuses heavily on internal factors such as confidence and self-esteem whilst being heavily critical of questionnaire efficacy in measuring motivation. Critically, it offers little in the way of establishing whether different approaches to science pedagogy have any influence on motivation. The application of PBL by Wong and Day (2008) shares prominence in this study as their work looks to underpin the place of PBL in science education. This is achieved by demonstrating how it improves pupils' comprehension of content and practical application of subject knowledge over extended time.

With these key sources complemented by a critical review of relevant literature I will describe an in-depth application of PBL in the classroom. This school-based research will show how PBL will affect intrinsic motivation and subject knowledge assimilation on a small population in a modern and diverse secondary setting.

Defining PBL

PBL has been described as an active way of learning that gives those involved better retention of knowledge whilst enhancing motivation (Maastricht University, 2018). Through PBL skills appropriate for the modern labour market are enhanced and infused. The ability to learn independently, and not just by rote, complement ones' place within a small team focused on thinking critically and problem solving (Maastricht University, 2018). PBL is used across the United Kingdom and worldwide and has a place in the medical based courses (Wood, 2003).

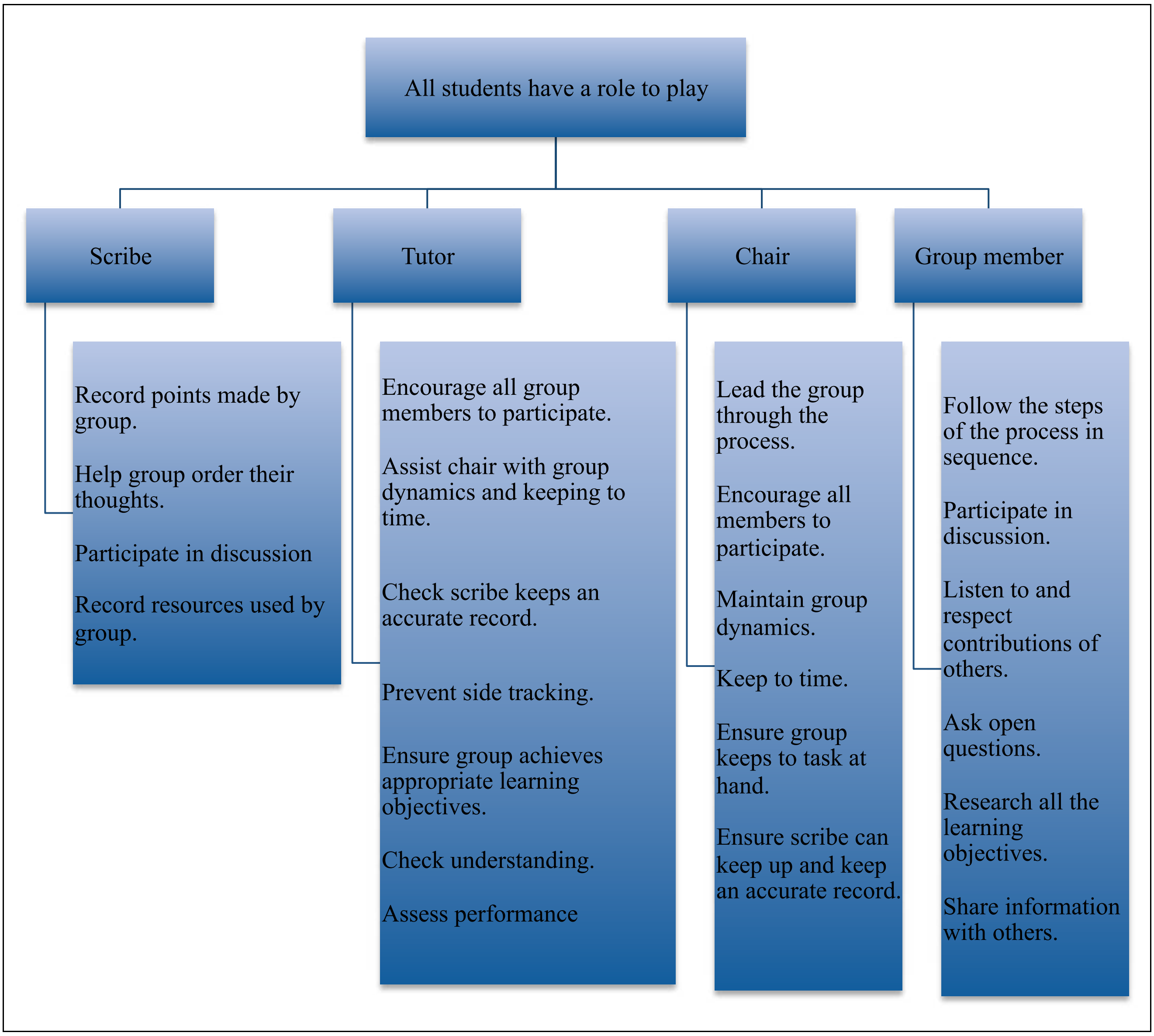

Figure 1: Role of participants in PBL (redrawn from Wood, 2003, p.928)

At the heart of this is the practical application in real life scenarios that subject knowledge is contextualised within. Thus, PBL's purpose is far greater than just "problem solving", it uses the wider skills of the learner in the defined roles of scribe, tutor, chair and group member. Each role was clearly defined (see Figure 1 above) to help increase knowledge and understanding through investigation (Wood, 2003).

PBL in practice

As previously mentioned, the work of Wong and Day (2008) shows the results of PBL in the classroom after six months of action research in a senior secondary (high school) science class in Hong Kong. What makes this study so interesting is that Hong Kong had a prolonged period of compulsory education from 1978 following a rigid rote learning syllabus from the Hong Kong Education and Manpower Bureau (HMB). Classes of 40-45 pupils were given scripted LBL, largely by teachers who had no specific pedagogical training nor were University graduates in their respective subject areas. As a result, Wong and Day (2008) could compare PBL to LBL in the most extreme of situations. This small-scale case study showed that PBL is at least as effective as LBL in gaining the content knowledge to pass exams. This work is focused on the education of pupils in Hong Kong, a culture very different to ours so their work would be carefully considered in this limiting context.

Supporting the small-scale work of Wong and Day (2008) is the large scale, federally funded, randomised controlled PBL experiment in teaching Economics to twelfth grade (seventeen to eighteen years old) pupils by Ravitz (2010). Data from seven thousand pupils taught by seventy-six teachers in sixty-six high schools showed statistically significant results in favour of PBL in content-based assessments. A flaw behind these findings is the teachers were given only five days of training on PBL before implementation. Results of classroom observations varied enormously across the study putting into question the validity of this training.

Large scale studies such as Ravitz (2010) were driven by data collected from studies such as Geier et al. (2008) who were keeping the momentum going from ten years' worth of educational investigation into inquiry-based science teaching in urban reform. Findings showed that those historically underserved by the education system were able to close the gap in attainment after eighteen months of PBL. The two cohorts of seventh and eighth graders, interestingly a lot younger than those focused on in Ravitz (2010), showed a greater content knowledge, skills acquisition and significantly higher pass rates in assessment. Comparison of this with the UK is difficult as this study was based in a different education system with culturally different pupils.

The implementation of PBL in practice has set the scene for a wealth of literature that realises the importance of active learning in improving educational attainment (De Witte & Rogge, 2016). This however is not without its critics. A substantial proportion of the evidence supports the attainment of those in higher education with the studies in high school proving less conclusive (De Witte & Rogge, 2016). Critics of PBL come from many different angles. Firstly, there is no clear definition of what PBL is and how it should be carried out (Colliver, 2000). Secondly, there is little empirical evidence on the impact of PBL in secondary education (Maxwell, Mergendoller, & Bellisimo, 2005). There are also non-significant and negative studies on pupil knowledge and skill acquisition (Gallagher & Stepien, 1996; Mergendoller, Maxwell, & Bellisimo, 2000; Burris & Garton, 2007). Highlighted within these is the difficulty that action research can encounter when applied in a secondary school context. Older secondary pupils may be more set in their ways and less likely to be receptive to a change of teaching styles in their respective subject areas (Wong & Day, 2008). In older pupils, especially those higher attaining and doing very well from LBL, there may be some selection bias and a temptation to not include these pupils in PBL studies (Colliver, 2000). Previous methodological shortcomings have been picked up by Colliver (2000), noting a tendency for pupils to "opt in" to the PBL group. The literature does consider that the youngest within secondary school may be the best suited to PBL in the classroom (Wong & Day, 2008). Considering their transition from primary to secondary there would be no preconceived position to how classroom learning and teaching should be carried out. This would lead them to be much more forthcoming to taking part in PBL, with no preconceived ideas of what method will get them the best grades in their exams (Marx et al., 2004; Mioduser & Betzer, 2007; Duncan & Tseng, 2010).

PBL…are you motivated?

Whilst it is generally understood that motivation in education is incredibly difficult to measure it is also clear that no teacher would ever doubt the need or importance of motivation in the classroom (Mubeen & Reid, 2014). So, what is motivation? Using the case of PBL it is pertinent to look at achievement goal theory as discussed by Seifert (2004).

Achievement goal theory can be broken down into two areas; performance and mastery and task. The premise of this is that pupils' behaviour in a classroom reflects their desire to achieve a goal (Seifert, 2004). Using the example of a top-set science class it could be deduced that those pupils pursuing mastery would be open to PBL, as their personalities foster a greater preference for challenge in their pursuit of cognitive development (Seifert, 2004).

As previously discussed, difficulty arises in measuring this. For those in the class whose personalities align themselves with performance goals, the impact of PBL may have a different effect. When considering the action research population, there must be careful consideration of this. As learners focused on their personal attainment and three years into LBL dominated secondary schooling, this new challenge may prove to be unwelcome (Seifert, 2004). This is not without due cause. LBL has served these learners very well in previous years allowing high exam grades and placement in the top-set for science. These learners will have to be closely observed. Poor behaviour and loss of focus can arise if they believe PBL is not serving their needs as LBL has in the past (Seifert, 2004). As described by Seifert (2004), I will have to look closely for any changes to the behaviour of the class due to the introduction of PBL (Figure 2) such as these could be positive or negative. By monitoring the class for maladaptive behaviours I can keep the emergence of task avoidance and possible anxiety to a minimum. As previously discussed this is a top set class that LBL has served well, I will need to ensure they remain task focused.

Reflecting on the literature, it is clear to that the place of intrinsic motivation in the science classroom is of the utmost importance. When considering every factor that could change the performance of a pupil in the classroom, intrinsic motivation plays a positive role, perhaps higher than any other (Ryan & Deci, 2011). Intrinsic motivation makes up the self-determined element of motivation. Even though very young humans have been observed to display a natural inclination to inquisitiveness the maintenance of this in a science classroom requires that there be certain conditions to support it (Ryan & Deci, 2011). Foremost in this is the need for PBL to, at the very least, stimulate and endure in the science classroom. Consequently, the momentum gained by the previous LBL series of lessons should not diminish the pupil’s enjoyment and interest in science.

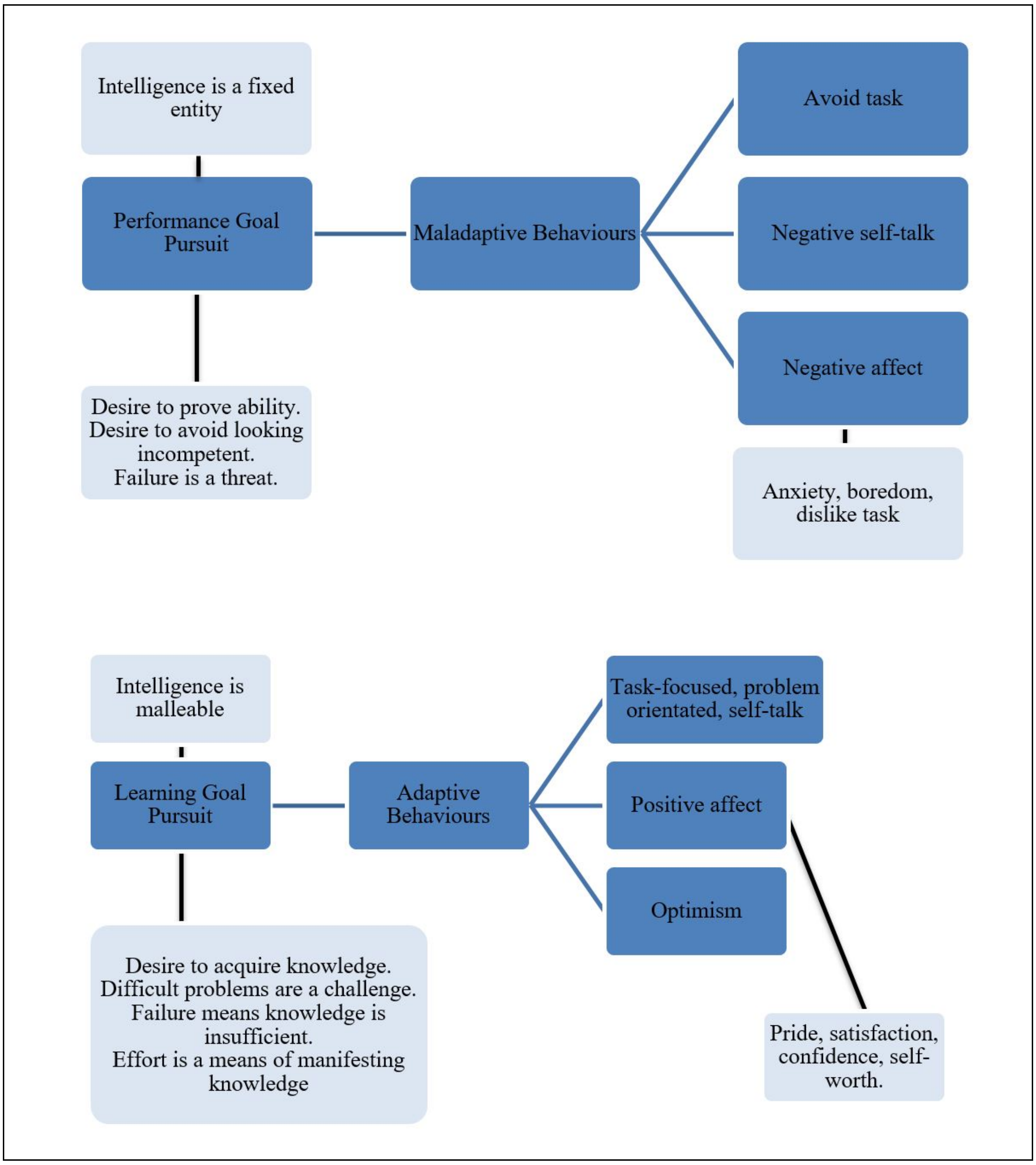

Figure 2: Characteristics of performance and learning goal-pursuit (redrawn from Seifert, 2004, p.142).

Cognitive dissidence and the importance of pupil's epistemological beliefs

Research about the constructive nature of pupils' learning provide insights into cognitive implications of PBL in the science classroom. Fundamentally speaking, a constructivist view of PBL would consider the pupil being actively involved in the process of learning. In contrast to LBL or rote learning, the pupil, fully engaged, would be constructing knowledge and meaning in a science classroom (Cakir, 2008). Vygotsky (1978) distinguished between independent learning in everyday life and systematic concepts of science taught in school. Analysis of Vygotsky (1978) shows there is an important connection between these two elements of cognitive development. What a pupil learns in school (content) has a direct influence on the development of concepts learned outside of school (contexts) and vice versa (Cakir, 2008). Crucially, PBL can bridge concept and context as it inherently has a system built into it. This is the difference between PBL and independent learning in its barest form. PBL encourages the pupil to reach an understanding of scientific concepts that will then influence their understanding of world.

Seen in this light, the relationship between pupil's epistemologies and their approach to science can greatly influence their preference to PBL or LBL, especially if this choice is the result of an ingrained expectation that secondary education, by its nature, is LBL based. Evidence in the literature does show a trend for pupils' who gain knowledge by LBL to have a logical empirical view of the world with those who approach scientific learning with a more constructivist approach utilising other methods of instruction more readily (Cakir, 2008). The relationship to increased cognitive development or simply correlation to higher exam results remains unclear.

Knowledge in Pieces (KiP) shows how pupil's prior conceptions impact the science classroom and reflect in their future learning. This epistemological perspective raises the interesting question of how we as science teachers deliver knowledge to pupils' (diSessa, 2004). Within the KiP literature is a breadth of argument that proposes within science and math there is a risk of building misconceptions, and an inability to demonstrate understanding past a cursory answering of questions (diSessa, 2004). This is largely due to the LBL method of science instruction and a lack of progress in the field over decades of measuring scientific understanding. By utilising PBL a teacher can involve the pupils in problem solving requiring contextualisation of knowledge, rather than simply memorising formulas, and accepting that they can answer questions without having a deeper understanding of what is going on (diSessa, 1993).

Further expanding on the constructivist theories of conceptual change is the literature on cognitive conflict in science education. Here it is argued that to learn new scientific knowledge the pupils must be actively involved to ensure their prior knowledge is reshaped and utilised (Dreyfus, Jungworth & Eliovitch, 1990). Cognitive conflict seeks to identify what the pupil already knows, then confront the pupil with contradictory information of the pupil's beliefs or theories (Limon, 2001). This whilst engaging the pupils in class discussion is different to PBL. PBL looks for the group to find meaning collectively to support prior knowledge or to widen knowledge by further investigation. Cognitive conflict may be happening on a sub-conscious level by the pupils, especially if religious or previously held beliefs are drawn into question. What PBL will seek is a group consensus with deeper discussion being encouraged as the group progresses on their learning journey.

The place of PBL in secondary education, its importance in developing wider skills and its ability to foster scientific investigation in a challenging inner-city school are all valid areas for investigative research in a broad and fascinating area. The literature encourages the use of PBL early in secondary education (Wong & Day, 2008) and with limited research on pupil intrinsic motivation in secondary education, further scientific investigation is warranted (Gallagher, Stepien, & Rosenthal, 1992; Gordon, Rogers, Comfort, Gavula, & McGee, 2001; Mioduser & Betzer, 2007; Baumgartner & Zabin, 2008; Achuonye, 2010).

Research Design and Methodology

Research Outline

Analysis of the literature revealed a variety of previous studies integrating PBL into the science classroom. It is suggested, that implemented at the right point of learning PBL can increase subject knowledge and skills acquisition (Gallagher et al., 1992; Mergendoller, Maxwell & Bellisimo, 2006; Mioduser & Betzer, 2007; Geier et al., 2008; Duncan & Tseng, 2010; Ravitz et al., 2010; Sungur, Tekkaya, & Geban 2010). This study focused on the research questions in Table 1.

Research Question 1 (RQ1)	How will a PBL series of lessons affect subject content assimilation in a top set KS4 physics class studying power?
Research Question 2 (RQ2)	How will a PBL series of lessons affect academic intrinsic motivation in the same class?

Table 1: Research questions considered during this action research project.

This research was carried out utilising the first cycle of an action research framework. In school-based research this is a systematic process of collecting data when a teacher has made a change to their practice (Wilson, 2012). Analysis of the data will look to apprise the success of these changes. Action research is always carried out by practitioners from within the organisation and never from external agencies (Wilson, 2012). Vitally, this is an approach undertaken by the classroom teacher whereby the novel approach is observed, compared against the literature and shared with colleagues. From here any changes to classroom workings may or may not take place considering the results. Figure 3 is based on Wilson's (2012) example of Action Research Cycle, It illustrates the four steps of Plan, Act and Observe, Reflect and Re-Plan along with a listing of tasks relevant to each of these steps.

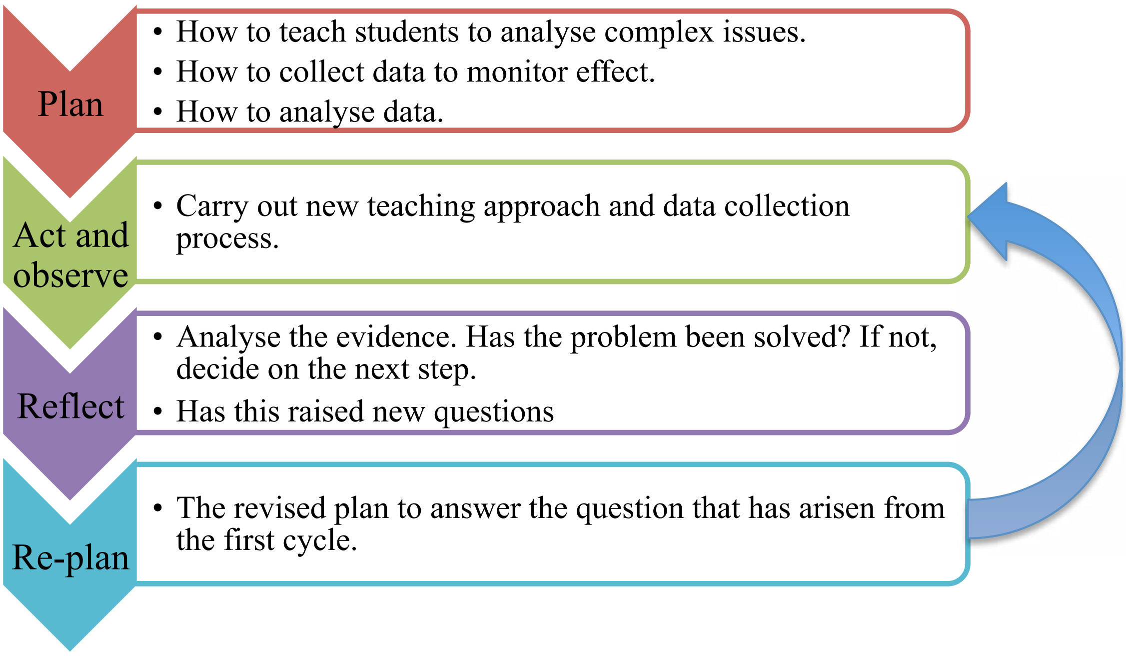

Figure 3: An example of action research cycles (redrawn from Wilson, 2012, p.191).

Research was carried out during Professional Placement (PP2) of school experience as part of the Post-Graduate Certificate in Education (PGCE) at the University of Cambridge. Due to the nature of this and time limitations only the first cycle of the action research model was carried out. Data collection was during the act and observe stage with critical analysis during the reflect stage (Wilson, 2012). I have chosen this method of research as it allows for a logical and reasoned approach to classroom research. The plan stage will reflect on the previous LBL series of lessons and be adapted to focus on the research questions appropriately. Reflection will allow the data and observations to be analysed considering the research questions and future hypothetical research cycles that could be carried out. This would be after further improvements to the original cycle had been addressed (Wilson, 2012).

Data Collection

Methods of data collection reflected the small population and allowed me to focus on the whole class and on particular pupils. This meant pupils chosen from a top, middle and lower attainment could add valuable insight to the study via interviews as well as whole class quantitative data. This method of utilising the population is described as convenience sampling and is a form of non-probability sampling (Wilson, 2012).

Pre and post-test diagnostic probes

To be able to measure subject knowledge improvement from the PBL series of lessons, two subject knowledge probes were used. The first, was at the end of the LBL series of lessons on energy, immediately preceding those on power. Comparison would be made against a similarly comprised test on power administered after the PBL series of lessons. Tests were constructed from previous exam questions utilising the 2018 version of ExamPro™. This type of probe is useful as it provides the classroom teacher with valuable insight to whether the teaching strategies are appropriate to the class and if the new content is being assimilated (Garrison & Ehringhaus, 2007). A limitation of this is that as a teacher I must be careful not to oversaturate the class with summative testing or this will become a preconceived assumption that the curriculum is defined by testing. This therefore could add stress to the pupils (Briggs, 2007) who consequently may not perform to their full potential.

Intrinsic Motivation Questionnaire

An intrinsic motivation questionnaire was carried out by all pupils at the end of the LBL series of lessons, after the post-test diagnostic probe was administered. Questionnaires totalled thirty questions and were taken from a larger scale study carried out by Mubeen and Reid (2014). This questionnaire followed a five-point Likert format (Mubeen & Reid, 2014). The survey was carried out in full on two occasions to ascertain if the PBL series of lessons had changed their motivation levels for science learning. Wilson (2012) discusses that giving the same questionnaire out to the same group twice may affect reliability. This is because pupils may remember the questions and answers. To alleviate this only the questions discussing intrinsic motivation and personal relevance (10/30 questions in total) were utilised in the results. As they are mixed amongst the other questions it is unlikely pupils will remember past answers.

Pupil Interviews

Interviewing pupils in the class took place after the series of PBL lessons. This interviewing allowed me to ascertain motivation levels for PBL in comparison to the LBL lessons the class had the most experience with. The questions were aimed at looking at the general motivation of the class for carrying out PBL and to ascertain if they felt it was worthwhile (Ryan & Deci, 2000). During the interviews in vivo coding was utilised to plot the amount of positive and negative responses to PBL. This allowed the conversation to flow with the observer quickly noting key points. A limitation of this kind of data collection is pupil interviews with open ended questions were used. This can result in vague or irrelevant answers which with a small interview population could lead to a collection of meaningless data (Johnson & Turner, 2003). It was my responsibility to consider this and ensure meaningful coding of the interviews.

Qualitative Observations

I was very fortunate that observation of the lessons was carried out by an incredibly experienced science teacher and mentor and the professional tutor assigned to the PGCE students. Accompanying my notes and lesson plans is the reflections of these incredibly experienced practitioners in the form of placement mentor observation notes.

Pupils' work from the LBL and PBL was also used as a point of reflection and discussion with the observers. During this I was able to code the work comparing similarities to each other and judge whether work had just been copied in rote.

Pilot Study

Before the main action research project was carried out a pilot study was administered. This ensured the protocols and data collection methods from the main study are suitably tested (Hassan, Schattner, & Mazza, 2006). By observing the class undertaking PBL I was able to observe who the clear leaders in the class were, the scribes or those carrying out the research elements and those who had the highest confidence to deliver the content. This helped to split down the class for the PBL lessons. The pilot study allowed for time appreciation and the approach to be validated making this a worthwhile exercise for myself and the class (Hassan et al., 2006).

Class and School information

This action research project was conducted at a mixed inner city British Academy school comprised of Indian, Pakistani, Eastern European and British (amongst many other nationalities), adding to a diverse and vibrant setting. The school has previously been rated as 'good' by the Office for Standards in Education (Ofsted). The class taking part in the study have been taught three times each week by me since January 2018. They are a top set class (n=30; 14 boys, 16 girls). They are currently undertaking P1 physics of the AQA GCSE syllabus (AQA, 2018).

Description of the intervention

After a previous LBL series of lessons on energy had been closed (with a summative test to be used as the baseline for the PBL), the class was briefed on what was to comprise the PBL in the following lessons. The Maastricht seven step process was utilised but after discussions with my professional tutor it was adapted for school-based application into 'The PBL 5 steps' (see Figure 4).

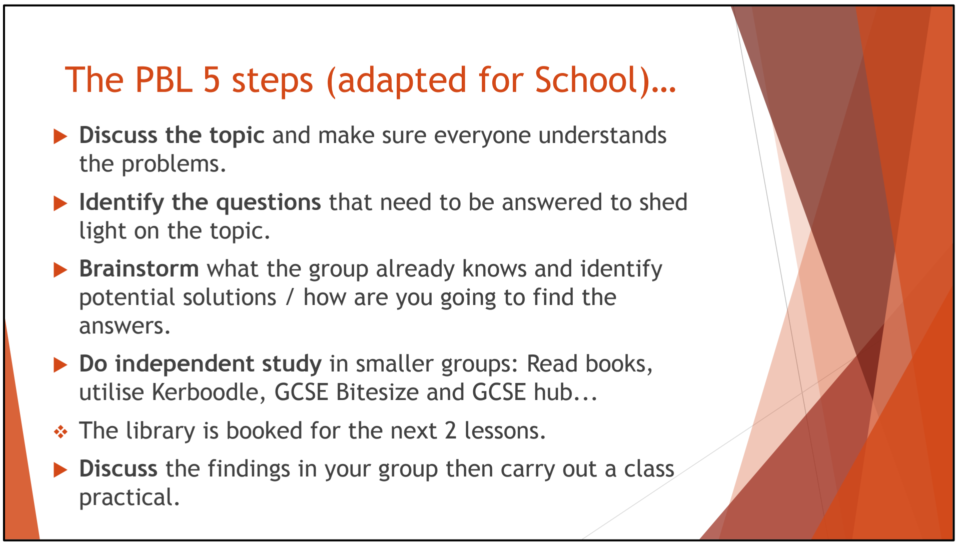

Figure 4: PBL 5 steps for school .ppt slide as discussed with the class. Adapted from Wood (2003) where a university setting was used.

To enable completion of these steps the class was broken down into seven groups created from the pilot study (Hassan et al., 2006). Roles of scribe, tutor, chair and group member were assigned to participants (see Wood, 2003). These roles were written down on flash cards that the member could keep in their exercise books. The following lesson started with the groups familiarising themselves with the study material.

The class were learning about power from the AQA energy in physics syllabus (AQA, 2018). For the PBL lessons the class would cover energy dissipation, energy efficiency, and energy & power. The class was told that on the third lesson they would carry out a practical on one of these areas. By utilising the resources available in the library, they were asked to work through the five points in Figure 4 over two fifty-minute lessons. Accompanying this was trigger material (Wood, 2003) made up of photographs which helped pupils link the learning objectives to contextualised applications. As defined by Wood (2003), other types of trigger material are paper based clinical scenarios, experimental or clinical laboratory data, video-clips, newspaper articles, all or part of an article from a scientific journal, a real or simulated patient, and a family tree showing an inherited disorder. Each group were given learning objectives. The literature would argue that in true PBL the learning objectives are defined by the pupils by studying a scenario (Wood, 2003). After many months of getting to know the class I felt that this was not the best approach for the class as they will lose focus if they do not have defined objectives from the outset.

On completion of the two lessons in the library the class was given a practical to carry out. No further guidance or lecturing was given. The class had access to the worksheets and all the equipment available to them on a trolley in the classroom. The practical was directed to ensure that even though the class were being offered a chance of learning freedom and independence, as their teacher I still needed to make a judgement that this was in their best interests. If the class were more proficient at PBL I would have offered the opportunity to design their own practical or even to decide if one was necessary at all.

Ethics

A plan of this research proposal was discussed with the subject lecturer in faculty. This subsequently was agreed. As per the PGCE guidelines the Faculty of Education ethics form was completed, signed and returned to the office before the planned study took place. From here further discussions took place between my mentor and professional tutor to fully involve the appropriate members of staff in a professional manner. There was strict adherence to the BERA code of ethics for educational research (BERA, 2018). Importantly, the class was kept informed of what was going on. So far as they understand, I am carrying out a master's programme of study and I have assured them than any information provided would be anonymised (Burgess, 2005). This ensures the study follows a strict moral and values code (Burgess, 2005). Pupils were further advised that any test they carried out in line with this project would not be used in the setting of or changing of target grades.

Data analysis and findings

This section will outline the results of the data collection and will consider each of the research questions in turn. Due to the small population size the data is presented in a descriptive manner (rather than using inferential statistics) to open discussion of the results.

RQ1: How will a PBL series of lessons affect subject content assimilation in a top set KS4 physics class studying power?

Pre and Post diagnostic testing

The scores for the pre-testing (after LBL series of lessons) and post-testing (after PBL series of lessons) are displayed in Table 2. Normal class size is thirty (Male N=16; female N=14).

	Male	Female
	17	19
	19	12
	14	18
	20	16
	18	18
	16	18
	16	10
	15	18
	18	16
	9	16
	13	19
	20	16
		10
Mean	16.25	15.846154
Mean %	65	63.4

	Male	Female
	19	13
	22	9
	8	10
	13	7
	16	16
	13	17
	14	16
	19	12
	10	16
	15	11
	11	8
	17	12
	18	10
	20	
	19	
	20	
Mean	15.875	12.076923
Mean %	63.5	48.3

Table 2: Pre and Post testing scores (pre left, post right).

The data shows that on both occasions there were pupils missing from the class (pre testing male N=4, female N=1, post testing male N= 0, female N= 1). For consistency in the scores the test was not offered to the absent members to prevent discussion of the test outside of class and the chance to revise which would have added anomalies into the results. The maximum score available was 25 marks.

Evident from the results is that pupils generally performed lower on the summative testing after the PBL series of lessons. These findings support the work of: Burris and Garton (2007); Mergendoller et al. (2000); and Gallagher and Stepien (1996). This is particularly evident for the females in the group. Reasons for this decline are most likely multi-variable. Analysis of the result must consider that the tests were in different subject areas and a control group utilising LBL before the summative testing was not used as a point of comparison. I cannot be sure a similar result would not have occurred after teaching this subject area with LBL. This has been addressed as much as possible by having the tests cover small and comparable areas of the energy syllabus (Wong & Day, 2008).

The literature does suggest that PBL, by its nature, enhances long term memory recall (Shin, Haynes, & Johnston, 1993) and immediate testing would not reflect this. Consideration to the fact that PBL is a new experience for the class must also been considered. As with any pedagogical tool utilised by the class PBL improves with practice (Benjamin & Keenan, 2015). Although content knowledge assimilation is essential to the success of a pupil in secondary education (as far as grades are concerned), we as academic practitioners must recognise that the skills utilised in PBL can empower pupils in a way that goes beyond the measure of summative assessment (Baumgartner & Zabin, 2008).

Qualitative Observations

PBL in the classroom… did it work?

Open coding of observations showed a positive effect on the group utilising wider skills to improve content knowledge. This was noted by myself and an observer to remove bias (Johnson & Turner, 2003). I carried out observations of the class during the PBL series of lessons alongside an accomplished substitute teacher who had previously taught this class in their early years at school. We both made hand written observations during the lesson and I carried out a post-lesson evaluation in line with PGCE requirements. Further observations of the practical lesson were carried out by the PP2 professional tutor. In summary the experienced professionals that observed the 1C PBL lessons were very impressed by the investigative skills displayed by the pupils', their peer to peer interactions and the group cohesion. Wider skills were being utilised. To the observer and author PBL was working.

PBL… A critical appraisal

As the class teacher I needed to delve deeper. Several trends were observed during the PBL series of lessons, especially assigned to the roles within groups. Those groups with a scribe who had a more artistic nature tended to make notes in their exercise books that were full of colour, flair and utilised techniques not discussed such as mind maps. It is worth considering that the scribes in the groups did appear to be those pupils that may be regarded as rote learners and were using the notation elements of PBL to improve their own content acquisition (and not that of the group) ensuring their own well-being was met (Ryan & Deci, 2000).

For those assigned the role of tutor, the lines between that of the tutor and chair became blurred. Generally, those with the confidence and leadership skills excelled. The tutor was in all cases a very able member of the class and through their work with the scribe, was able to keep learning focused around the learning objectives. Through not wanting to change group dynamics the tutor generally left the role of encouraging group members to the chair as they did not want to adversely undermine their authority. What was apparent in many of the groups was the tutor looking to replicate resource material in their exercises book essentially by rote. These finding support the work of Lloyd-Jones and Hak (2004) where medical undergraduates exposed to PBL manipulated their tutorials to ensure their outcomes met the resources provided by the faculty.

The chair of the group, essentially those with a natural flair for leadership within their peers, directed the group but in many instances remained distracted. By allowing the natural leaders of the group to take the chair positions I essentially allowed these to dictate to the scribes what to write or type, then resort to ‘chit chat’. On many occasions I had to use his time around the groups to keep the chair on target as the groups, especially in lesson two of three started to fracture. The ability to keep their focus consistent was not fully apparent. This is discussed more in the finding of research question two looking at motivation.

Evidence from pupils' work

After each lesson I marked pupil’s books to understand what they had individually taken away from PBL. As expected from the roles in PBL the actual written work reflected roles within the group. The scribe has detailed writings whilst the tutor effectively wrote nothing and had a copy of a Power-Point their scribe produced. The 'group member' had notetaking comparative to that of the scribe but in not as much detail. This was still, in my opinion, taken down in rote. These finding are supported by the work of Lohman and Finkelstein (2000) who found that their groups had difficulty in simplifying information exchanges successfully.

Group members, whose role mainly was to follow in the discussion and participate essentially became assistants to the scribe in every group. The small size of the groups encouraged this to happen naturally and I did not feel this was detrimental to the nature of the lesson. Encouragement came in the form of pushing the group member towards reading the content and contributing where they felt comfortable. Generally, the strengths of the peers around them pushed many into assistant scribe positions. This left unrecognised by the group may have resulted in many members sat idly, while others in the group carried out the work. In this instance the PBL acted as a social context for pupils with a lower ability to self-direct their learning to contribute (Lloyd-Jones & Hak, 2004).

RQ2: How will a PBL series of lessons effect academic intrinsic motivation in the same class?

Pre and Post PBL Academic Intrinsic Motivation Questionnaire

The responses to the motivation questionnaire provided a telling response to the gender differences regarding intrinsic motivation. The data from Table 3 shows that more females than males moved opinion from 'agree' to 'strongly agree' after PBL.

Pre:1	I take pleasure in learning science.				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	5	9	0	0	0
Female	1	6	3	1	2
Total	6	15	3	1	2
Post:1	I take pleasure in learning science.				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	5	9	1	0	0
Female	4	7	2	0	1
Total	9	16	3	0	1

Table 3: Intrinsic motivation - Pleasure in learning.

Data from Table 4 shows that both males and females gain a positive effect considering their opinion on 'grades not being as important as their knowledge' after PBL.

Pre:16	Receiving high grades in science is not as significant to me as the science I learn.				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male		3	10	1	0
Female		2	6	1	4
Total		5	16	2	4
Post:16	Receiving high grades in science is not as significant to me as the science I learn				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	0	6	6	4	0
Female	1	2	4	4	3
Total	1	8	10	8	3

Table 4: Intrinsic motivation - Grades vs Knowledge.

The data from Table 5 shows a positive effect as more males and females move from indifferent to agree.

Pre:22	I find it interesting to study science				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	7	4	3	0	0
Female	4	3	3	1	2
Total	11	7	6	1	2
Post: 22	I find it interesting to study science				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	8	9	0	0	0
Female	4	6	3	1	1
Total	12	15	3	1	1

Table 5: Intrinsic motivation - Interest in science.

Results from academic motivation questionnaire focusing on intrinsic elements from (Mubeen & Reid, 2014).

Due to some members of the class being away, numbers slightly differ between pre and post questionnaires. In the pre-population male (N=14), female (N=13) with a total of 27. In post-population male (N=16), female (N=14) with a total of 30 (full class). As detailed in the methodology only the questions regarding intrinsic motivation have been included to keep the focus on RQ2. Full results of these ten questions are available at Appendix 2. These three questions have been detailed here to allow for short, succinct and meaningful discussion of key findings in line with the research question.

Qualitative Observations

Effort and enthusiasm

Observations of PBL were favourable with respect to pupil motivation, especially during the practical lesson with coding reflecting a positive outcome. Every practitioner that witnessed the 1C lessons was impressed with the amount of effort displayed by the class. Moreover, the displayed enthusiasm for wider skills utilised by PBL impressed beyond any feedback regarding the content from the lesson mirroring discussion in Lohman and Finkelstein (2000).

Novelty and pupil motivation

From observations the most memorable quote was "Sir, if we're doing all the work what's the point of you being here?" This again shows the pupils' lack of contact with novel teaching methods and an expectation of LBL as a norm (Wong & Day, 2008). This however was the exception to the feedback given. Many pupils were genuinely happy for the change of scenery to the school library, enjoyed being given the freedom to learn independently. Those with negative responses were the very academic rote learners who displayed genuine dismay at not being in the LBL setting that they had become accustomed to. This is observation is supports discussion in the literature review about pupil's epistemologies and their approach to science learning. It is clear their preference to LBL is the result of an ingrained expectation that secondary education, by its nature, is LBL based (Cakir, 2008).

Pupil Interviews

The approach

After the series of lessons was complete, interviews with three members of the class took place to ascertain their motivation for PBL in-line with RQ2. The sample size was small mainly because of time constraints at the school. There are no breaks other than a thirty-minute lunch break so the only time available was after school on a Wednesday as I taught this class last period. Class members could stay behind for a maximum of fifteen minutes in accordance with school rules. This aside, the interviews proved very informative and I was able to capture data from a top, (pupil 1, male) middle (pupil 2, female) and lower seated member of the class (pupil 3, female). The sex of these pupils' was purely random from availability and does not reflect the tiered ability of the class. Class data came from my class folder which contained their predicted grades for this school year. Interview preparation was in-line with Wilson (2012) and lasted no more than three minutes each.

PBL… a novel teaching method

Through the discussions with interviewees it was clear that PBL was regarded as a novel approach to their learning with no teacher trying this with them previously. When compared to LBL one of three pupils stated vocal preference to LBL over PBL. I do believe this was more due to their extrinsic focus on attaining high grades over an intrinsic one. Self-efficacy theory does point out those that see themselves as capable are more likely to be motivated than those who believe themselves to be incapable (Siefert, 2004). With this being their first introduction to PBL their confidence may be low, but this does not reflect their ability to do well in science or other subjects, it is just a reflection of this situation (Siefert, 2004).

Evidence

Coding of the conversation did reflect the work of: Achuonye (2010); Mioduser and Betzer (2007); Baumgartner and Zabin (2008); Gallagher et al. (1992); and Gordon et al. (2001), showing an overall positive impact on pupil motivation in the classroom, especially where their personal curiosity was encouraged. Extracts from the conversation are included below for review.

When asked if they understood the reasons for using PBL in school they were all able to repeat some of the earlier class discussion on the reasons for PBL:

> *Pupil 1: "it's important to be able to work well in a team as well as on your own".*
>
> *Pupil 2: "I just want to get the best grades I can as I want to be an Optometrist".*
>
> *Pupil 3: "I'll do what I have to. I don't really enjoy science anyway".*

Here 'positive' comments are made by pupil 1 and 2 reflecting intrinsic and extrinsic motivating factors (Ryan & Deci, 2000). It became apparent with this question that pupils did understand to a degree why PBL would be useful in school, but they were perfectly comfortable with LBL. This supports previous discussions into pupils' epistemological belief and the work of Wong and Day (2008) that suggests there is an inherent indoctrination to the ways of LBL that is difficult to remove.

Consideration of any skills that have improved or gained because of their role in PBL drew interesting responses.

> *Pupil 1: "I was a scribe and I was able to just focus on the text book and books from the library and note down everything I needed. It then helped me remember it by sharing it with the group".*
>
> *Pupil 2: "In the library lessons I didn't really have a clue what to do so I just copied out of the books and helped my friends".*
>
> *Pupil 3: "I was a group member and just sat with my friends going over the bits on GCSE Bitesize. It was good though I enjoyed it".*

Here pupil 2 and 3 mention 'friends' with pupil 3 mentioning 'group'. This highlights how PBL has focused on wider development of skills within peers with the goal of the group or friend learning facilitating knowledge acquisition (Wood, 2003).

Discussion

RQ1: How will a PBL series of lessons affect subject content assimilation in a top set KS4 physics class studying power?

Data from the pre and post PBL data probe showed the population of the studies scored 15.1% lower in comparable tests after a series of PBL lessons. In this instance the class performed better after LBL. Supporting this is the findings of the pupil's work which I feels demonstrates that many of the class applied rote learning, copying from books and websites into their exercise books. Linking this discussion back to the literature review these findings support the work of Burris and Garton (2007), Mergendoller et al., (2000) whose studies found that those in LBL classrooms displayed better content knowledge development than those in PBL. The work of Burris and Garton (2007) is useful as PBL or LBL classrooms were randomly assigned to alleviate bias from the study. The bulk of the previous literature on PBL does show an improvement on content knowledge as an associated outcome with this study joining the small group showing a negative impact. To have seen an improvement in the populations acquisition in content knowledge over such as brief period would have been favourable to this study but would not have truly reflected the complexities of PBL. Undertaking PBL with the sole purpose of improving subject knowledge is a long-term process requiring the engagement of not just the pupils, but the teachers and schools involved (Mioduser & Betzer, 2007).

The collection of qualitative observations does provide some of the strongest evidence of the effectiveness of PBL in the classroom. Mentor observations, coding and discussion show a rich and vibrant learning environment where pupil participation and meaningful interactions with peers are prevalent. This type of observation is to be expected as PBL positively encourages pupils to problem solve, work as a team and discuss as a cohesive group (Dochy, Segers, Van den Bossche, & Struyven, 2005). Also apparent from the discussions during class was the extreme polar perceptions of those that were getting on very well with it and those that were unsettled and preferred LBL (Struyven, Dochy & Janssens, 2008a; Struyven, Dochy, Janssens, & Gielen, 2008b). With the importance of education not just providing content knowledge but actively improving the skills and attributes of the pupils' it is important see how the pupils' learned during PBL as ultimately positive.

In looking at the effectiveness of PBL I have shown many positives on pupil interactions with work on the technique and implementation needed to bring the study in-line with the bulk of the literature supporting improved acquisition of content knowledge. Pupils are familiar with being inspired and motivated by their teacher's positivity and charisma, a strength of LBL, rather than learning independence that promotes curiosity and interest (Wong & Day, 2008). This is a product of an education system extrinsically focused on exam grades but does little to develop intrinsic motivation (Wong & Day, 2008).

RQ2: How will a PBL series of lessons affect academic intrinsic motivation in the same class?

Observing the data from the intrinsic motivation questions in the questionnaire shows that more pupils' took pleasure in learning science (Q1), found it interesting to study science (Q22) and found success in understanding science (Q30) after the PBL series of lessons. These findings support the work of: Achuonye (2010); Mioduser and Betzer, (2007); Baumgartner and Zabin, (2008); Gallagher et al. (1992); and Gordon et al. (2001). A weakness of these results is the lack of any statistical analysis, but this would have been of no use in such a small population (Wilson, 2012). Interesting observations do come from looking at the marked difference of males and females in the population. Of note males find science more interesting, feel success in understanding science and enjoy the challenge of science supporting the findings of Stark and Grey (1999). Difficulty with measuring motivation comes from an assumption that it is one variable that can be measured (Mubeen & Reid, 2014). The reality is that multi-variable analysis is needed. The focus of intrinsic motivation in science was incredibly narrow. Whilst motivation can be influenced by the teacher there are many other powerful factors involved that are out of the control of the classroom (Mubeen & Reid, 2014). This result may have come from the pupil's low confidence in PBL as found during pupil interviews. Pupil motivation has been shown to increase when they have confidence in their learning and perceived value in learning activities (Reeve, Nix & Hamm, 2003). With this positive attitude meaningful understanding of new science can build on their previous knowledge (Mubeen & Reid, 2014). It was clear from the pupil interviews that the pupils were focused on getting the task done quickly rather than taking any real meaning or value from it. With extrinsic motivation for grades still being prominent this study supports the evidence from the literature showing a trend for top pupils who gain knowledge by LBL to have a logical empirical view of the world (Cakir, 2008).

Conclusions, limitations and implications

Conclusions

Interesting analysis and discussion of the use of PBL in the science classroom has arisen from this first cycle of action research study. Even though the quantitative data did not show an improvement for PBL over LBL qualitative observations were positive towards its use. The use of PBL in this study suggests that wider skills such as teamwork, leadership and co-dependence can be developed at the expense of subject knowledge acquisition but with a positive impact on academic intrinsic motivation. Noted by myself and observers was a strong group dynamic and willingness to learn through shared experience. Highlighted in this study are worthwhile areas for further research into a novel pedagogical tool that has the potential, when used appropriately, to enrich the classroom and develop many wider skills for the pupils'. These claims are made cautiously in the light of the limitations that will be further discussed.

Limitations

Two main limitations have been identified in the methodology and are outlined further in this section. These lie with the intrinsic motivation questionnaire and the qualitative data collection. Further smaller limitations of this study are also noted. These were my lack of experience with PBL, the class's lack of experience with PBL, the small timescale that the PBL was utilised and the expectation that meaningful intrinsic motivation change could be effectively measured within this time frame.

Limitations of the academic intrinsic motivation questionnaire (RQ2) comes more from the way the data would be analysed (Mubeen & Reid, 2014). Due to the size of the population (n=30) it would not be meaningful to use data analysis such as Kendall's Tau-b for ordinal data as seen in the questionnaire; the population is just too small. No statistical analysis or t-tests was used. Data was placed into the principal components of the questionnaire that reflect the research questions and are shown as descriptive side by side (before and after PBL) to allow for analysis of the results and discussion. Further limitations of the pre and post PBL questionnaire could be that the class had just previously undertaken a practical before filling out the post 1c questionnaire. Observations reflect how much the class was enjoying it and results from pupil's response may differ as a result (Braund & Driver, 2005). Finally, it is worth reflecting on a pupil's motivation for filling out a thirty-question long paper at the end of a lesson.

Observing pupil's motivation (RQ2) was harder to quantify than that of subject knowledge assimilation. Here there are many factors at work. Rather than just observe I had to talk with pupils individually to encourage this information to surface. As alluded to in the methodology a limitation of this was the presence of the school management and a teacher that had taught them through the previous two school years. Discussions were more likely to reflect what they perceived we wanted to hear than what they really thought. During lesson 2/3 there was more of a chance for honest feedback due to neither of the aforementioned personnel being present.

Implications for further practice and research

The bulk of PBL literature and evidence is based around further education so the scope of research at secondary level is vast. This study supports the work of Wong and Day (2008) who also noted that due to the prevalence of LBL in the classroom pupils' struggle to adopt new learning practices and apply to content knowledge acquisition. This becomes more apparent the longer the pupil has been in education. It is therefore recommended that PBL is implemented from the start of secondary education as noted in the literature review by: Marx et al. (2004); Mioduser and Betzer, (2007); and Duncan and Tseng, (2010).

This cycle of action research looks to make the following recommendation to classroom practitioners (Table 6), as well as future cycles of action research to be carried out on this area.

	RECOMMENDATION
1	Implement PBL as early as possible in secondary education. That way it become a normal rather than novel teaching method.
2	Utilise PBL over longer timeframes so pupils can become accustomed to their independence and find meaning in their endeavours.
3	Use PBL during areas of the science curriculum that complement the project nature of the learning rather than the equation-based elements traditionally taught by LBL. Examples of this could be global energy resources (physics), respiration and exercise (biology) and fuel cells (chemistry).

Table 6: Recommendations for future practice and research using PBL based upon the findings of this study.

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Appendix 1

Science intrinsic motivation questionnaire

When I am in a science class…. (tick the box that applies)

*Are you **Male** or **Female** (Delete as applicable)*

Item	Statement	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
1	I take pleasure in learning science.					
2	My personal goals and objectives associate with my science learning.					
3	It always concerns me that other pupils perform better in science.					
4	It makes me anxious about how I will perform in a science exam.					
5	I seek to understand if I find difficulty in learning the science.					
6	When the time comes to take a science test I will feel anxious.					
7	It is essential and valuable for me to get high scores in science.					
8	I learn science with great interest and put in adequate effort.					
9	I employ different approaches that ensure I learn science well.					
10	The science I learn can assist me to find an excellent career.					
11	I think about the science learning and how it will help me in my profession.					
12	I expect to achieve better in science than other pupils.					

13	It makes me worried to think about a weak performance in the science exam.					
14	I try to perform as well in science tests as compared to the other pupils.					
15	I take my science performance seriously.					
16	Receiving high grades in science is not as significant to me as the science I learn.					
17	How science will be obliging or useful to me is considerable.					
18	I do not like to even think of science exams					
19	How I will employ the science which I study in daily lives and in future is significant to me.					
20	I am personally responsible if I do not get the science well and am weak in understanding					
21	I am sure to perform better in science practical's or projects.					
22	I find it interesting to study science.					
23	Science has realistic worth for me.					
24	I am confident in my abilities to perform well in a science exam.					
25	Science learning is associated or pertinent to my existence.					
26	I prepare well for science tests.					
27	When I learn science, I like that it challenges me.					
28	I am sure on my capabilities and competencies in science.					
28	I am positive that I can achieve '8' grade in science.					
30	I feel success in understanding science.					

Appendix 2

Data from science intrinsic motivation questionnaire

Pre:1	I take pleasure in learning science				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	5	9	0	0	0
Female	1	6	3	1	2
Total	6	15	3	1	2

Post:1	I take pleasure in learning science				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	5	9	1	0	0
Female	4	7	2	0	1
Total	9	16	3	0	1

Pre:2	My personal goals and objectives associate with my science learning				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	6	7	1		0
Female	4	5		2	2
Total	10	12	1	2	2

Post:2	My personal goals and objectives associate with my science learning				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	2	9	4	0	0
Female	5	5	3	0	1
Total	7	14	7	0	1

Pre:11	I think about the science learning and how it will help me in my profession				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	6	7	1	0	0
Female	4	5	2	0	2
Total	10	12	3		2

Post: 11	I think about the science learning and how it will help me in my profession				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	4	7	3	1	
Female	4	6	2	1	1
Total	8	13	5	2	1

Pre:16	Receiving high grades in science is not as significant to me as the science I learn				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male		3	10	1	0
Female		2	6	1	4
Total		5	16	2	4

Post: 16	Receiving high grades in science is not as significant to me as the science I learn				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	0	6	6	4	0
Female	1	2	4	4	3
Total	1	8	10	8	3

Pre: 19	How I will employ the science which I study in my daily life and in future is important to me				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	4	7	3	0	0
Female	4	6	1	0	2
Total	8	13	4		2

Post:19	How I will employ the science which I study in my daily life and in future is important to me				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	5	8	1	2	0
Female	3	7	2	1	1
Total	8	15	3	3	1

Pre:22	I find it interesting to study science				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	7	4	3	0	0
Female	4	3	3	1	2
Total	11	7	6	1	2

Post: 22	I find it interesting to study science				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	8	9	0	0	0
Female	4	6	3	1	1
Total	12	15	3	1	1

Pre:23	Science has realistic worth to me				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	7	5	2	0	0
Female	5	6	0	0	2
Total	12	11	2	0	2

Post:23	Science has realistic worth to me				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	7	6	3	0	0
Female	6	5	1	1	1
Total	13	11	4	1	1

Pre:25	Science learning is associated or pertinent to my existence				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	2	7	5	0	0
Female	3	4	4	0	2
Total	5	11	9	0	2

Post:25	Science learning is associated or pertinent to my existence				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	2	9	5	1	0
Female	2	3	6	2	1
Total	4	12	11	3	1

Pre:27	When I learn science I like that it challenges me				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	3	7	4	0	0
Female	1	3	6	2	1
Total	4	10	10	2	1

Post:27	When I learn science I like that it challenges me				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	5	7	4	0	0
Female	2	4	6	1	2
Total	7	11	10	1	2

Pre:30	I feel success in understanding science				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	5	9	0	0	0
Female	3	4	3	1	2
Total	8	13	3	1	2

Post:30	I feel success in understanding science				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Male	8	7	1	0	0
Female	4	5	3	1	1
Total	12	12	4	1	1

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