www.sails-project.eu

Report from evaluation of implementation with pilot teachers - Part A

SAILS
Strategies for Assessment of Inquiry Learning in Science

Strategies for Assessment of Inquiry Learning in Science

D 3.1 Report from evaluation of implementation with pilot teachers - Part A

Authors: Christine Harrison, Paul Black, Benő Csapó, Csaba Csíkos, Erzsébet Korom, Paul van Kampen, Odilla Finlayson, Eilish McLoughlin and Deirdre McCabe
Project name: Strategies for the Assessment of Inquiry Learning in Science (SAILS)
Project number: 289085
Start date: 01/01/2012
Duration: 48 months
Lead partner for this deliverable: Kings College London
Project coordinator: Dublin City University
Contact: info@sails-project.eu
Website: www.sails-project.eu

The research leading to these results has received funding from the European Union's Seventh Framework Programme for research technological development and demonstration under grant agreement no 289085

Contents

1. Introduction

The aim of SAILS is to support teachers in adopting an inquiry based science education (IBSE) at second level (students aged 12-18 years) across Europe. In addition to adopting IBSE curricula and implementing teacher education, the SAILS project will develop appropriate strategies and frameworks for the assessment of IBSE skills and competencies and prepare teachers not only to be able to teach through IBSE, but also to be confident and competent in the assessment of their students' learning. Through this unified approach of implementing all the necessary components for transforming classroom practice, i.e. teacher education, curriculum and assessment around an IBSE pedagogy, a sustainable model for IBSE will be achieved.

As detailed in Deliverable 1.1, the SAILS project distinguishes three distinct categories of activities—**what scientists do** (e.g., conducting investigations using scientific methods), **how students learn** (e.g., actively inquiring through thinking and doing into a phenomenon or problem, often mirroring the processes used by scientists), and a **pedagogical approach that teachers employ** (e.g., designing or using curricula that allow for extended investigations) (Minner, 2009). However, whether it is the scientist, student, or teacher who is doing or supporting inquiry, the act itself has some core components.

Inquiry based science education is an approach to teaching and learning science that is conducted through the process of inquiry. Some of the key characteristics of inquiry based learning are:

- Students are engaged with a difficult problem or situation that is open-ended to such a degree that a variety of solutions or responses are conceivable.
- Students have control over the direction of the inquiry and the methods or approaches that are taken.
- Students draw upon their existing knowledge and they identify what their learning needs are.
- The different tasks stimulate curiosity in the students, which encourages them to continue to search for new data or evidence.
- The students are responsible for the analysis of the evidence and for presenting evidence in an appropriate manner which defends their solution to the initial problem (Kahn & O'Rourke, 2005).

These characteristics are reflected in the NRC's "essential features of classroom inquiry". These include:

- "*Learners are engaged by scientifically oriented questions.*
- *Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.*
- *Learners formulate explanations from evidence to address scientifically oriented questions.*
- *Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding*
- *Learners communicate and justify their proposed explanations"* (NRC, 2000, p. 25)

Within an inquiry culture there is also a clear belief that student learning outcomes are especially valued. One characteristic of inquiry learning is that students are fully involved in the active learning process. Students who are making observations, collecting data, analyzing data, synthesizing information, and drawing conclusions are developing problem-solving skills. These skills fully incorporate the basic and integrated science process skills necessary in scientific inquiry. A second characteristic of inquiry learning is that students develop the lifelong skills critical to thinking creatively, as they learn how to solve problems using logic and reasoning. These skills are essential for drawing sound conclusions from experimental findings. While many projects have focussed on the evaluation of conceptual understanding of science principles developed, there is a clear need to evaluate other key learning outcomes, such as process and other self-directed learning skills, with the aim to foster the development of interest, social competencies and openness for inquiry so as to prepare students for lifelong learning. For an extensive discussion of the Key Skills and Competencies Framework adopted in the SAILS project, see D1.1.

2. Assessment of Inquiry Skills

Much of the literature on inquiry in science looks at the way such approaches strengthen conceptual understanding (Bredderman, 1983; Shymansky, Hedges, & Woodworth, 1990; Wise, & Okey, 1983; Lott, 1983; Schroeder, Schott, Tolson, Huang, & Lee, 2007; Gee, & Wong, 2012). However, you cannot really separate the two aspects of science since any inquiry draws on current understanding to ask questions and any observation relies on current understanding to make inferences. We therefore don't think we can treat assessment of science inquiry as being totally separate from subject knowledge assessment. Instead, we think the SAILS pilot study should encourage teachers to adopt an inquiry style approach to their classroom activities and then to allow them to identify and collect assessment data as the learning is taking place. This data will arise from observing and listening to the students in class and from the products that learners generate as part of classwork and homework. The drive for the type of assessment comes not from sources different from those which teachers normally use in the classroom but from the approach they take – an inquiry approach.

2.1 Part A: Non-Diagnostic Assessments and Inquiry

Deliverable 2.1 has given an extensive overview of assessment with a focus on diagnostic testing. In what follows, we highlight a different aspect of assessment. In classrooms, the main purpose of assessment is to support and encourage learning. Teachers need to find out in real-time what and how their students are thinking about the learning so that they can plan what steps to take next. This formative approach to assessment means that teachers are continually seeking feedback from their students about their confidence with the topic being studied: this is an essential part of helping them to learn, and so assessment runs alongside the learning. It is often desirable to obtain this feedback without stopping to test the students as this may detract from the learning. Instead the teacher uses subtle questions and challenging tasks to help her students reveal their current level of understanding.

Tests can play a useful role in formative assessment in that they can help teachers make a quick assessment if, for example, a child has moved from another school and so the teacher is unsure of what the child has achieved so far or if the teacher isn't confident with the assessment evidence they have collected for a particular aspect of work. In these cases, the test data can add to the teacher's assessment of that student and this helps teachers in both reporting on the child's learning to parents and in deciding what the next steps in learning might be. In other words, the test data along with the teacher's on-going assessments work both summatively and formatively.

Inquiry skills are what learners use to make sense of the world around them. In science classrooms, these include problem solving, planning and carrying out investigations, looking for patterns in data sets, making observations and inferences, asking questions and researching and testing out their ideas. This approach not only helps youngsters develop a set of skills that they will find useful in a variety of contexts, it can also help them develop their conceptual understanding of science.

Recalling that a plant grows because it photosynthesises and produces sugars is not the same depth of understanding as when students approach plant nutrition through inquiry.

An inquiry approach fits within a constructivist paradigm in that it requires the learner to take note of new ideas and contexts and to question how these fit with their existing understanding. It is not about the teacher delivering a curriculum of knowledge to the learner but rather about the learner building an understanding through guidance and challenge from their teacher and from their peers. So, the learning experience is different from so-called traditional lessons where the teacher simply presents ideas and asks questions about these. Instead, the teacher sets up activities where the children are actively involved in making sense of ideas as they are generated through classroom talk.

2.1.1 An Inquiry Style Lesson

In an inquiry style lesson, the teacher might show the class an oak tree and an acorn and ask “How did this acorn grow into this large tree? Where did it get its building blocks from? What did it use for food?” In listening to the children discuss these ideas in groups, the teacher is able to find their starting point for these ideas, to locate any misconceptions that they may have and to begin thinking about which activity may be useful for taking their ideas forward.

It may be that the children believe that the acorn has taken materials from the soil as the main building blocks for growth and, in this situation, the teacher may lead the learners through some guided inquiry to grow plants hydroponically so that their ideas are challenged when they realize plants can grow without soil.

Alternatively, the children may realize that light has a role to play in the process but they can’t relate this to nutrition. Again a guided inquiry approach where the children test potatoes, yams, leaves, bananas and rice for starch may help with their developing conceptual understanding.

A good question at this point might be –“If light helps plants grow then why aren’t the largest plants found in the desert?” Again, discussion of this question in groups helps pupils voice their inquiries and develop their curiosity, while at the same time providing the teacher with data about their level of understanding. Such a discussion also provides a bridge into getting them to start thinking about the variables involved in photosynthesis.

The teacher could then model the effect of light intensity in photosynthesis by immobilizing some algae in gel balls and placing them in containers of hydrogen carbonate indicator at a variety of distances from a light source. As the algae remove carbon dioxide through photosynthesis, the indicator changes colour (see e.g. saps.org.uk) Modelling an investigation and encouraging discussion about controlling and manipulating the variables helps the learner see inquiry skills in action. It also allows the teacher to judge how well some students might be able to design and carry out their own investigations. In other words, it is providing insights into both their conceptual understanding and their developing capability with inquiry.

So, when it comes to the learners developing their own inquiries about the effects of the colour of the light or the temperature of the hydrogen carbonate solution or the concentration of the algae in the gel balls, both the teacher and the learner have some idea about the amount of support that particular learners might need to complete the task and what questions they need to ask to move the activity and the learning forward.

Throughout this sequence of inquiry approach activities, the teacher is getting feedback from her learners and is able to use this information to build a better understanding of each student’s progress. At the same time the teacher is able to know better what to do to help individuals, whether in providing more support or in asking more challenging questions. The learner meanwhile, is drawn into the learning scenario through both working collaboratively with others and by being continually challenged with the questions and activities that the teacher is devising or selecting.

2.1.2 So are tests redundant in an inquiry style approach?

The assessment data arising from the class activities may reduce or obviate the need for giving a test. There is no reason why a teacher should forego giving a test or use test items either part way through or at the end of the learning sequence. The question that the teacher needs to ask herself is whether she needs to carry out a test if she already has sufficient assessment data arising from the class activities. Tests take time to devise and mark for the teacher, and they can reduce the time a class might have to do their various learning activities. Therefore tests are most useful as formative assessment if they provide the teacher and the students with additional information about the students' learning. For example, it may be that the teacher uses a test, or some items from a test, at some point in the learning sequence to allow the learners to see how their understanding has moved forward since their earlier discussions about the acorn and the oak tree. The teacher might also use some data questions on photosynthesis from an external examination to see if the learners can make sense of the data in the items from their understanding developed through inquiry. Equally, the learners could be asked to criticize an investigation on light intensity from the inquiry they did in class. For example, they may look at data which, which measured oxygen released from pond weed instead of the effect of algal balls on hydrogen carbonate indicator, and the assessment would look at whether they could transfer the skills and understanding they developed in their inquiry to this second investigation. This would enable the teacher to see whether the learner could apply their conceptual ideas in a different context. These types of questions could also assess whether students could use their investigative skills to the same degree when they were working things out from drawings and descriptions rather than carrying out the investigation manually.

2.1.3 How confident can we be in assessment data from inquiry lessons?

Observing learners in the classroom as they carry out investigations, listening to learners piece together evidence to answer a challenging question in a group discussion, reading through answers to homework questions and watching learners respond to what is being offered as possible solutions to problems all provide plentiful and rich assessment data for teachers. Such data place teachers in a good position to sum up the progress and to have a realistic awareness of each learner's understanding by the end of the learning sequence of activities.

This type of assessment has high validity. It satisfies one of the conditions for validity in having high reliability, in that the learner is assessed on several different occasions, thereby compensating for variations in a learner's performance from day to day, and in several ways, thereby sampling the full range of learning aims. The fact that the learner has been assessed in contexts which have been interspersed with the learning secures both coverage and authenticity, particularly because the teacher is able to test and re-test her interpretations of what the data mean in relation to each individual's developing understanding. Such data place teachers in a good position to sum up the progress and to have a realistic awareness of each learner's understanding by the end of the learning sequence of activities. This is radically different from assessing the learner in the artificial context of the formal test, and affords invaluable different insights into the learner's potential to both use and to extend her learning in the future.

2.1.4 How can we help teachers collect assessment data from inquiry lessons?

Teachers need to recognize and collect the assessment data that arises from inquiry lessons. To do this they need to think carefully about the variety of ways in which learners might respond to the new ideas or new contexts or challenging question being offered. Being aware of a quality answer to a problem will help teachers easily recognize whether a child has or hasn't got that understanding. A way forward might be to ask the teacher to highlight each of the challenges in an inquiry lesson and to note how good understanding of that challenge could be demonstrated.

By listening carefully to answers to questions or to group discussion or by scrutinizing products from inquiry activities, teachers can gather evidence of their learners' emerging understanding. Teachers can note misconceptions, identify partly answered questions from full answers, and recognize errors and possible reasons why such errors are occurring. Such data is rich in inquiry lessons because the very nature of the approach means that the lesson is challenging and so understanding is interrogated.

2.1.5 Do we need a framework for looking at inquiry skills and do we need test items?

We think the answer to both these questions is YES.

A framework for the assessment of inquiry skills will tie in with the report from work package 1 and help us make more sense of our approach to inquiry. We believe it will help us define what we mean by inquiry and provide some insight on how such skills tie in with broader skills relating to learning to learn and desirable 21st century key skills.

Selecting or devising test items to exemplify this framework will help us check on the stability and capability of the framework. Having such a framework will also be useful to Workpackage 4 and 5 in supporting the professional development and learning of teachers and pre-service teachers.

2.2 Part B: Recording evidence

If a teacher is to translate the principles set out in Part A into regular practice she will need to have apply a variety of methods to use the various assessment opportunities that arise during inquiry-based learning. The methods that might be useful will be of two main kinds, as follows:

2.2.1 Assessing the whole Class

One kind are methods which involve every pupil in the same way and at the same time, so giving the teacher data about every individual. The obvious examples are activities in which every pupil has to produce written work. These can include

- written tasks set as pieces of homework;
- end-of-topic tests

The value of these will be enhanced in pupils are given opportunities to improve on their work in the light of feedback. Such feedback might be the comments that a teacher might give on the homework, or a requirement to re-work their weakest responses in an informal test, or challenges arising as pupils mark one another's work in small groups.

- in the classroom, an experimental demonstration may show a phenomenon and all asked to write down how they think the phenomenon might be explained, and how they might investigate their explanation.

This can lead to peer group discussion and then each pupil could be asked to add revision statements to their original ideas. The teacher can then collect these, and return them after looking through them and recording her evaluation.

It might help such procedures if each and every one of the written products of an individual learner's work were kept in a single book or folder - a portfolio for each pupil of the progress of her achievement over a year of work. Assessment of such collections would be both formative and summative, with the emphasis on the former most of the time, but use for the latter at the end of a term or of a school year.

2.2.2 Assessing a Sample of the class

Methods in which, on any one occasion, the teacher collects data for selected pupils only. Such data may be involve the teacher making a record of

- the contributions the selected pupils make to a whole class discussion,
- observations of the way in which the pupil works at a task, possibly supplemented by discussion with that pupil,
- observations of selected pupils when they are chosen to report to the whole class the conclusions reached in their group's discussion.

It is obvious that for this type of record a teacher can only produce evidence for a few (say 4 to 6 depending on the type of observation) pupils in any one class period. Then the teacher may set up a schedule so that every pupil is observed, in sequence from time to time, so that comparable records are available. However, such a scheme may be varied, with fewer occasions for pupils who are consistent and or not problematic, to allow for more observations for others. As in all work of the FIRST kind above, these occasions should involve feedback and opportunities to improve – they should not become formal tests.

2.3 Part C: Interleaving the formative and the summative

It should be clear from the discussion in Parts A and B that one basic feature in any improvement of assessment is that the same evidence may be used for both formative and summative purposes. It is simply untrue that the formal test is intrinsically more valid than the collection of diverse pieces of evidence of the type described above. However, both parents and school managements might need convincing that the judgments of any individual teacher are free of bias and are evidence about the same aims, and are judged by the same standards, as those of other teachers and schools. Several methods may be used to satisfy such concerns, as follows:

- Written records of the occasions and judgments collected for each individual pupil over (say) the year, combined with a collection of that individual's various pieces of written work produced during that year.
- Collaboration between teachers, within and/or between schools to exchange samples of such records and inter-calibrate their judgments.
- Using formal written tests as one element of such collections, which may be used as calibration instruments to check the general standards (but not to iron out differences of individual pupils).

There are particular projects where such approaches have been implemented, and there are national systems in other countries where they are well established routines which have replaced the dominance of external testing by the use of inter-calibrated teachers' assessments. What is significant about all of these examples is that the teachers and schools involved find that the time spent in the planning and cross checking of their methods and standards has had a very positive effect on all aspects of their work, so that what may be seen initially as an extra burden becomes a valued part of their professional development.

Some may be concerned that for any piece of work that contributes to a summative assessment it is 'unfair' that the pupil has opportunity to use feedback to correct her work before the final judgment is made. This is a feature of formal tests, but is not necessarily an advantage. The learner who can make good use of feedback to improve her work is thereby a better learner than one who cannot do so.

2.4 Development of Initial Assessment Items

As already detailed in D2.2, the working document (M33) outlined an approach to assessment of science inquiry that enables teachers to create opportunities in their classrooms for both formative and summative assessment.

A small group from WP2 and WP3 over a two day workshop devised an approach to developing assessment items for each country to pilot with experienced teachers that provided opportuniy for both formative and summative assessment opportunities in their own classrooms. Three topics were selected to provide physics, chemistry and biology teachers with a view of the type of assessment opportunities that could be developed within each of their subject areas; these topics chosen for the first assessment items were Food, Rates of Reaction and Speed aimed at the lower second level students. These topics were chosen so as to be most applicable across all countries.

Within each topic, the content knowledge was based on that required at lower second level. Proportional reasoning was identified as the key reasoning skill to be included and then of the inquiry skills, the skill of planning an investigation was highlighted in the assessment topics.

The materials were initially trialled by the England Teachers Group on 6th March 2013 and then sent out to all other countries involved with a brief description of the teacher workshop and its outcomes. The England Teachers Group were enthusiastic about the assessment activities and were keen to pilot these in their schools over the following weeks. They reported back on the assessment activities at a meeting on May 15th 2013, a day prior to the London Project Meeting for all countries. This enabled colleagues from the other countries to hear how the pilot activities had been received by the teachers in England.

3. Discussion and Piloting of first three assessment items

Teachers who are experienced in IBSE were identified in each country. The pilot assessment materials (as given in Appendix 1) were discussed and trialled by teacher groups in several partner countries. It was not possible for all partners to pilot these materials in this first piloting phase because:

- The topics for the pilot materials selected did not fit with the curriculum for this time of year
- The level selected within the pilot materials did not fit with the classes taught by the teachers
- It was not possible to hold workshops for the teachers over this time period
- The teachers were not yet at a sufficient level of competency with teaching inquiry skills or lacked the confidence to include assessment within the learning experience.

Nevertheless, several groups were able to discuss and/or trial the pilot materials and the reports below from England, Ireland, Poland and Germany provide a summary of how the materials were received and used by their teacher groups. It is hoped that other countries will trial the pilot materials or use the pilot materials to develop or adapt their own inquiry assessment materials over the next few months.

3.1 Pilot Teacher Feedback - England

The teacher pilot group met in March and, as part of the workshop, they tried out the three sets of activities that had been developed looking both at the feasability of each activity and also pinpointing which aspects of inquiry they felt able to assess during each activity. The teachers were generally enthusiastic about the activities, seeing their relevance within the curriculum and in developing inquiry skills in their students. The teachers then trialled the activities in their schools and reported back on this in a meeting in May.

3.1.1 Biology teacher group

The biology teachers reported that the food labels activities worked well and that the activities increased student engagement. One of the teachers adapted the Food Card activity so that initially it was more directly guided by the teacher and used the activity to encourage the learners to decide on the different criteria for a balanced meal compared to a desirable meal. He reported that several misconceptions regarding balanced diet were evident in the discussions throughout this activity but recognised that some of the students making these in the early part of the lesson had sorted out their ideas more correctly by the end of the activity. Another teacher was surprised to find that her students could easily focus on a difference between foods but not on similarities within the FOOD CARD data. She also noted that initially students selected extreme differences and so replacing one food with another while trying to keep the whole meal balanced proved quite a challenge. Some students struggled with the mathematics calculations when trying to compare portions of food.

In the Vitamin C investigation, one teacher decided to make the activity completely open-ended as he introduced it at the end of a run of more guided inquiry activities. The aim was for the students to explore what they felt was possible to investigate with the DCPIP inquiry and to come up with a testable question. He used peer assessment for students to compare and evaluate one another's methods. He found that many of the students could recognise faults within methods but did not have sufficient skills to feedback to their peers. For example, some students added DCPIP to the juices directly and so could not go on to compare the differences in Vitamin C in the different samples and the evaluating students simply said that the method was poor, instead of explaining why or giving guidance on how to improve the method.

The teachers noted that there was a dilemma in terms of assessment. If the method was strong then it was difficult for the students to produce anything worth assessing in the evaluation part of the inquiry. On the other hand, if the method was initially poor then the students could either use another group's method or be directed more by the teacher and this allowed them to produce a good evaluation. The teachers discussed how the more open-ended an inquiry was, then the greater the possibility for weak or different types of approaches leading to more opportunities for critiquing, which they realised were difficult to achieve when the teacher guided the inquiry more directly.

The biology teachers reported that they were able to assess the following in the Food Labels Activity:

- Organization of the data,
- Proportional comparisons,
- Analysis
- Drawing conclusions
- Applying knowledge

The biology teachers reported that they were able to assess the following in the DCPIP inquiry:

- Formulating questions
- Formulating methods
- Evaluating methods
- Analysis
- Drawing conclusions

3.1.2 Physics teacher group

One of the physics teachers tried the How Fast Can You Walk? Activity. She noted that the students, of their own volition, pooled apparatus so that they could work in larger groups and was pleased at the demonstration of collaborative behaviour by the class. They were aware that this approach reduced the error in their measurements. Another teacher reported that his group had difficulty converting the different units and this reduced the effectiveness of the inquiry. While the two teachers decided that it was difficult to assess individual competencies while doing the activity, they reported that it was possible to gain insights into the strengths and weaknesses of groups and to use this evidence to inform teaching in a formative way. They noted the importance of using different levels of inquiry and different amounts of scaffolding with different groups

3.1.3 Chemistry teacher group

The chemistry teachers felt that their learners were initially confused by the Rates of Reaction activity, but that by the second lesson, the activity started to develop into a good inquiry. One teacher approached the activity in a more guided way than the other and the group discussed the versatility of the activities in general in that they allowed the teacher to adapt the activities to the skill level of the classes they were teaching.

The chemistry teachers were able to assess the following in the Rates of Reaction activity:

- Making and testing a hypothesis;
- Analysis;
- Assessing evidence;
- Teamwork.

3.1.4 Whole group

The teachers also discussed using the Fradd et al framework from the Primas project.

- Some teachers found the differences among analysing, applying, evaluating, and concluding confusing. The group discussed that they interpret analysing as presenting the data in an organised way, and concluding as stating to what extent the results are valid, and what are their implications.
- Some teachers suggested adding a column for "evaluation" in the table about levels of inquiry.
- Teachers should start with a low level of enquiry and then go up on the scale. Students should be guided first and then allowed to approach in a more open way as they improve their Inquiry skills. The teachers mentioned the importance of letting students make mistakes and giving them feedback.
- They discussed that open-ended inquiry helps students reach different outcomes and felt that this could lead to more easily identifying student's strengths and weaknesses. They recognised that when the teacher guided the inquiry that it was more difficult to assess both across a range of skills and sometimes individual differences in competency since guidance increased the amount of scaffolding and direction given.

While the teachers were able to recognise which inquiry skills they were able to assess within the activities, they were less clear on how they would report these assessments. This was partly because they had some concerns on distinguishing assessment of individuals from assessment of groups, partly because they recognised that they may have scaffolded some groups/individuals more than others on some parts and so were unsure of the effect of this on the performance in other parts of the inquiry and partly because they had not fully decided on how to do the assessment. Most of the teachers favoured using a system that they had used recently when assessing investigations for GCSE examinations. This involved conceptualising the inquiry in four parts – planning, observing/collecting results, analysis and evaluation. The teachers felt able to describe a range of performance under each of these four areas.

3.1.5 Conclusions

In conclusion, the teachers found the activities feasible and well received by their students. One important point that the teachers stressed was that they felt that using the assessment activities simply on final reports produced by their students would have resulted in them missing many aspects of inquiry carried out by the students and so assessing simply the outcomes would have been insufficient in terms of assessment. The teachers reported that they noticed both strengths and weaknesses in individual, group and whole class assessment skills and competencies by assessing them as part of the learning experience and this enabled them to either support individuals or to adapt their teaching in a formative manner, while still collecting sufficient data on students to make summative judgements if these were required. This suggests that the approach to assessment taken by the SAILS project enables teachers to make an more authentic and more valid approach to assessment than simply providing assessment items to check on learning after the inquiry or a rubric to judge the report of the inquiry.

In some of the schools, fellow teachers also tried the activities and generally were positive about the activities. The teachers were able to recognise the assessment opportunities within the activities and explained how they used evidence from different stages of the activity to provide feedback and guidance to their students. The teachers were less confident in using the evidence in a more summative way and felt that the Fradd et al framework from the Primas project did not help with assessment, although it was useful in helping them recognise the degree of openness in an inquiry. The teachers felt they needed more structure and support in making judgements about the inquiry skills of individuals if the evidence was to be used for reporting.

3.2 Pilot Teacher Feedback – Ireland

Seven experienced teachers in IBSE attended a day-long session at Dublin City University in March .

Teachers were divided into subject groups and assigned a topic of speed, food labels or rates of reaction. For each topic, the teachers were asked to firstly discuss the key concepts that could be covered by these topics and how they would assess them. The teachers were asked to think of both everyday assessment and pre/post assessment. Following their discussion for about an hour, they were given the draft SAILS materials on these three topics to discuss how they could assess these inquiry lessons.

3.2.1 Biology teacher group

The biology group initially focussed on the food labels. Having examined the Food Labels material from SAILS, they considered it suitable for the Irish curriculum, but they felt that the introduction was too mathematical and assumed greater proficiency in proportional reasoning than students typically have when the topic is taught (typically students are aged 12-13). Teachers decided that by starting with food labels, omitting the original questions 1-3, and reworking questions 4-7 so that the numbers were easier to work with, the materials were suitable for their classroom.

The physics teacher group also briefly reviewed the "food labels" topic. The first concern of the teachers looking at this material was that it was not very inquiry based, and the first activity was just a series of maths questions. On looking at the questions further, they then did see some merit in including them, and felt that the final question of the activity did link everything together in an inquiry based manner.

An overall concern highlighted throughout the day by the teachers was how they might be constrained in practice by both time and the curriculum. All of the teachers remarked on how all of the activities had a large focus on relationships between variables and "proportional reasoning". Some of the teachers wondered would this be too much for some students, and how it could be difficult to include something to cater for all levels of ability.

3.2.2 Physics teacher group

The physics teachers group were keen to make a link between the science and maths syllabi, but had concerns about the topic being approached consistently across the two subjects. They see the topic as a key way to teach graphing methods, and also for students to learn about units and accuracy in experiments. While the main focus of their discussion was mostly on experimental skills and processes, they also discussed what students may understand about speed, and the idea of "distance/time" vs "distance travelled/time taken".
With regard to assessment, the group talked about how they could distinguish student learning in terms of skills/concepts/knowledge. Minor adaptations would be needed to this draft to apply to the Irish curriculum
Uniform acceleration is not part of the curriculum, so this material was not considered.

3.2.3 Chemistry teacher group

The chemistry group were very much content-focused. They discussed reaction rates, reactions of metals with acids, and how students could measure gas production, control the variables – such as amount of metal, etc.

With regard to the SAILS document on reaction rates, the first concern that the group had was its relation to the syllabus. They felt that although the activities contained a broad range of material, only a very small part of it was directly relevant for the lower secondary science curriculum. They did feel however that what was included could be a useful platform for teaching other, more relevant parts of chemistry. The teachers found the range of material quite broad, and thought that Junior cycle students would have some difficulty with the mostly open nature of the material. They decided that a more guided inquiry structure was required, with a focus on graphing and acids and bases.

3.3 Pilot Teacher Feedback – Poland

3.3.1 Biology teacher group

The Food Label materials were trialled by the Biology teachers in their schools – only the part about development of research skills (detection of vitamin C) was completed. The remaining part of the unit, developing mostly reasoning and comparative inference skills (packed lunches, food cards, washing lines) will be implemented later when discussing the topics related to the rules of healthy diet.

The lesson was conducted in the second grade of lower secondary school (14-15 year olds). Due to the shortage of reagent (DCPIP), the experimental procedure was modified and iodine was used together with starch solution as an indicator. After a demonstration by the teacher which showed that the dissolved vitamin C tablet caused a change of the solution color, students took part in a brain-storming session considering the possibilities of application of this method in practice. Subsequently they formulated research questions independently, put forward hypothesis and planned the research with support from the teacher. After elaboration of the procedure, the students performed the experiments on the vitamin C content of juices, drinks, dissolved vitaminised candies, etc. The results were analyzed in groups and conclusions were drawn. The results obtained in all groups were gathered in one table, enabling every student to examine a complete comparison. Subsequently the students discussed if the method allows you to determine not only relative but also the absolute content of vitamin C in food products. As a conclusion the students pointed out the need of scaling the method and proposed a way to do it.

The teachers felt that the content proposed in this unit, the form of implementation and the assessment model are fully understandable and appropriate for the third level of schooling (lower secondary school, ages 13-16). The unit develops skills in compliance with new curriculum, both in aspect of research and reasoning skills as well as in aspects of comparative inference. In addition it enables students to connect theory with practice and promotes healthy living. It can not only be applied in our schools, but also seems to be an effective didactic approach.

A second group of biology teachers looked at the Food Label materials but did not pilot them in their school. They felt that the first part of the unit (packed lunches and food cards), which developed reasoning and concluding skills, was not adequate for the upper secondary school (ages 16-19) and that the unit is more appropriate for the lower secondary school (ages 13-16), especially if considering the aspects of healthy diet rules.

The second part of the unit, concerning an investigation on vitamin C, seemed a useful way of developing and assessing research skills. The practical aspect makes it interesting for students. However it seems to be necessary to make minor modifications to the procedure in order to enable the students to extend the method to estimating the absolute content of vitamin C in food products. The content, and the form of execution, proposed in this section, are completely understandable and after that small correction about scaling the method, they appear to be appropriate. A model of assessment, based on Fradd methodology (Fradd et al, 2011), enables an effective evaluation of the developed skills. It seemed feasible to implement this part of the unit at upper secondary level.

3.3.2 Physics teacher group

A group of physics teachers reviewed the speed task and felt that some of the activities were clear but others needed more detail. They felt that with minor changesit is definitely possible to implement the unit at school. They thought it was very important that only low cost materials have been used in the activities, which should encourage more teachers to use the activities.

The activities linked with the following parts of the new Polish physics curriculum.
a) At the third level of education (lower secondary school):

1. a pupil reads a velocity and a distance out of the graphs presenting distance vs. time and speed vs. time, as well as draws the graphs on the basis of text description."
2. in experimental requirements "calculates velocity of a moving object (…) by conducting measurements of distance and time"

b) At the fourth level of education (upper secondary school)

1. "a pupil draws and interprets graphs representing parameters of motion vs. time"
2. In experimental requirements a pupil draws and interprets the graphs "e.g. obtains acceleration in uniformly accelerated motion"

The skills developed in this unit are in full agreement with the new physics curriculum

The teachers felt that no assessment model was included in the activities and a more detailed consideration of the assessment within each activity was required.

A second group of Physics teachers looked over the speed materials. The content of particular activities was thought to be clear and understandable. The content was mostly suitable for lower secondary school, although it can be also used during the introductory lesson for mechanics for upper secondary school. The implementation of the unit through the questions asked to the student give him/her the possibility to gain the knowledge, learn how to generalize and draw the conclusions, independently. The questions are based on everyday context, so the introduced concepts are less abstract.

The proposed activities would be motivating for students and would encourage student to learn from and to analyze their surroundings. They felt that the unit can be definitely implemented in Polish schools. It is more suitable for lower secondary (13-16 yrs) than for upper secondary, mostly because of the way of implementation (i.e. the lack of formulas, relations and graphs). The equipment is relatively low cost. For example, the experiment with reaction time can be done with use of a long ruler and a piece of paper. The most important adjustment is the change of units into

SI units, used in our curriculum. However it can be interesting to introduce as well the nautical mile, equal to 1,852 km and extend it to knot unit as a unit of velocity on the sea.

The physics teachers felt that no assessment model was proposed.

3.3.3 Chemistry teacher group

A group of chemistry teachers looked at the Rates of Reaction materials The unit was not implemented at school but the teachers saw the possibility to do it later in the school year. In the Polish chemistry curriculum for lower secondary and upper secondary school (basic level) the topic of reaction rates does not exist. Nevertheless, the proposed activities can be used during classes when talking about:

Properties of carbonates or CO2 (lower secondary school)
"Chemistry supports our health", in which the student (chemistry curriculum) explains what the healing and toxic properties of chemicals depend on (dose, solubility, fragmentation, penetration into the body) such as aspirin, nicotine, ethyl alcohol;
Searching for information about influence of components of common medicine (activated carbon, aspirin, substances neutralizing excess acid in the stomach).

The teachers felt that the content and the implementation suggestions proposed in the didactic materials are clear. It is worth noting that the method of drawing graphs proposed by the authors may cause difficulties, because the students have no knowledge about molarity.

In terms of carrying out assessment within the activities the teachers felt that as they are not trained to assess students' learning in IBSE, the assessment tool should be more detailed. This should include emphasising which skills are to be focused on, i.e. to check if the student is able or not to formulate a research question, to plan and perform the experiment, etc. They felt that the current materials were unclear on how to assess student activity. They also felt that the assessment should also take into account student engagement, trials of solving problems, interesting (non-standard) solutions.

A second group of chemistry teachers did not implement the Rates of Reaction materials in school but they did ask their students to try them at home. The teachers felt that the content is presented in an understandable way and that it is possible to do the proposed experiments in group-learning activities both at basic and advanced level. A student gathers the chemical knowledge through research – s/he observes, verifies, draws the conclusions, generalizes. A student safely uses laboratory equipment and chemicals; s/he design and conducts chemical experiments. S/he put forward hypothesis trying to explain chemical problems and plans the experiments to verify them; on the basis of performed experiments s/he formulates opinions independently. So in conclusion, the skills developed in the unit are in agreement with the current Polish curriculum. The form of implementation proposed in the materials was interesting and understandable.

It would be worth including self-assessment questions at the end of the unit and other supplementary questions, which will help the student prepare a better research report, e.g.:

- Write briefly what the results show
- Use graphs and data to justify your hypothesis.
- Do the results support or reject your hypotheses?
- Have you checked if:
    - the title of the figure describe appropriately what is In the figure?

- the axis scaled and named? Are units included?
- the scale right? (Does it start from zero? Are units equally separated?)
- the data points are accurately inserted into graph?

3.4 Pilot Teacher Feedback – Germany

The materials *Food*, *Reaction Rates* and *Speed* have been studied in the project group at LUH and some additional information have been requested from the leader of WP 3. It was difficult to use these materials or some of the activities in the regular teaching at school by our teachers because the subjects are often not being taught by them at this time of year. We concentrated instead on analyzing and commenting on the materials.

Since the teachers of cohort 1 wanted to know more about assessment and assessment strategies in the first kick-off-meeting, we integrated a theoretical and a practical part on assessment in one of our follow-up meetings with fourteen teachers in April 2013. In the theoretical part we gave a brief overview about the concepts of summative and formative assessment, traditional and non-traditional tasks and showed a few concrete feedback examples.

The teachers worked in small groups. For each activity in the materials they were asked to comment on:

1. assessment strategies: a) How can learning be assessed?
   b) Which skills can be easily/difficult assessed?
2. the relevance for teaching: a) Estimate the relevance of these activities to your own teaching.
   b) How would you use these activities? (→ table of Fradd et al. 2001)

We provided about an hour for this task in the workshop. The group discussed various aspects of the materials intensively. Due to time constraints and the fact that most teachers are physics (and math) teachers, the group work was concentrated around the physics materials.

The main aim of this task was the activation of a lively and serious discussion on the topic of assessment. This aim was achieved. For example, some teachers brought into the discussion their own variation of the activities. The evaluation of the written materials shows the difficulty of the task and the possibility of different interpretations of the activities. For example, the activities (or parts of the activities) can be used in different phases of teaching or for different age groups. The teachers identified different skills that can be assessed like planning an investigation or collecting/measuring data (e.g. "recognize physics models in their living environment"), saw problems in the activities (e.g. "supervision is not possible in this activity/part") and estimated the relevance for their own teaching (ranging from highly relevant to irrelevant). We learned from this task too that it might be important to work with teachers on a more concrete level of teaching practice. For example, it might be useful not only to discuss what to assess but also to discuss how to assess in specific teaching situation, as we did in the theoretical part, by showing as an example flash cards.

A followup meeting with this pilot teacher group is planned after the summer break.

4. Summary of Piloting of Initial Assessment Items and Implications

Feedback from the pilot teachers was generally favourable. They generally felt that the approach to assessment of inquiry skills was feasible within their classrooms. The assessment opportunities allowed them to collect evidence of individual, group and whole class competency in specific inquiry skills, and to use evidence from their assessments to make judgements (summative assessment) and to inform their teaching (formative assessment). Some of the teacher groups felt that they learnt more from carrying out the assessment alongside the learning than if they had simply assessed the final report of the inquiry activity.

Some pilot teachers felt that they would like (or might need) more detailed notes on what skills to assess within each activity and which criteria to use to support them in making judgements. At this stage, these teachers had not, at that point, trialled them with their students in the classroom. Moreover, some of the partners in the SAILS project indicated that they would like additional guidelines or experience to improve the quality of their workshops with non-specialist teachers.

This feedback informed the SAILS meeting in May 2013. A number of workshops were organized with the explicit aim of giving the partners a deeper understanding of how to run an effective workshop on embedding assessment within inquiry activities. This, in turn, led partners to modify the content of the workshops that they had planned for their teachers. As an example, a plan for a modified 2.5 hour session on Reaction Rates used in Ireland is included in Appendix 2.

Bibliography

Bredderman, T. (1983). Effects of activity-based elementary science on student outcomes. A quantitative synthesis. *Review of Educational Research, 53,* 499-518. doi: 10.3102/00346543053004499

Gee, K., A. & Wong, K. K. (2012). A cross national examination of inquiry and its relationship to student performance in science: Evidence from the Program for International Student Assessment (PISA) 2006. *International Journal of Educational Research*, 53, 303-318. doi: 10.1016/j.ijer.2012.04.004

Lott, W. G. (1983). The effect of inquiry teaching and advance organizers upon student outcomes in science education. *Journal of Research in Science Teaching, 20,* 437-451. doi: 10.1002/tea.3660200507

Schroeder, C. M., Schott, T. P., Tolson, H.Huang, T.-Y., & Lee, Y.-H. (2007). A meta-analysis of national research. Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching, 44,* 1436-1460. doi: 10.1002/tea.20212

Shymansky, J. A., Hedges, L. W., & Woodworth, G. (1990). A reassessment of the effects of inquiry-based science curricula of the 60's on student performance. *Journal of Research in Science Teaching, 27*, 127-144. doi: 10.1002/tea.3660270205

Wise, K. C. & Okey, J. R. (1983). A meta-analysis of the effects of various science teaching strategies on achievement. *Journal of Research in Science Teaching, 20,* 419-435. doi: 10.1002/tea.3660200506

Appendix 1: Pilot Materials

1 Investigating Food

1.1 Why teach this topic?

This is a topic that is returned to many times throughout a child's time in school and one of the main reasons for including it in the curriculum is the hope that children will begin to understand what makes a healthy balanced diet. From this stance they can then look at their own diet and that of others and make recommendations about how to improve the diet. The problem however is that too often the ideas behind obtaining a balanced diet are not considered in sufficient detail to allow youngsters to understand what a balanced diet means in reality with foods simply categorized as healthy or unhealthy or as fat or protein and the true composition of foods and the amounts needed to keep someone healthy are not looked at. So youngsters are not equipped with sufficient knowledge and skills to make the choices that they need to when it comes to their own diet. This set of materials attempts to help with developing better ideas about food and incorporates an investigative approach to aid the skills development required and also to motivate students to want to understand these ideas better.

We will be looking at two different types of skill in this topic. The first is the skill of **proportional reasoning** because the students will need to be able to compare different amounts and types of food in their diet. The second is a raft of skills that fall under the umbrella of **investigative/process skills.**

1.2 Background Information

A healthy diet involves consuming appropriate amounts of all essential nutrients and an adequate amount of water. Nutrients can be obtained from many different foods, so there are numerous diets that may be considered healthy. A healthy diet needs to have a balance of fats, proteins, and carbohydrates, calories to support energy need and micro nutrients (vitamins and mineral salts) to meet the needs for human nutrition. Fibre in the diet also bulks the food intake and keeps the gut contents moving.

The following table lists the Daily Values (DVs) & Recommended Daily Intakes (RDIs) based on a calorific intake of 2,000 Cal, for adults and children four or more years of age.

Nutrient	DV
Saturated Fatty Acids	20 g
Cholesterol	300 mg
Sodium	2400 mg
Potassium	3500 mg
Total Carbohydrate	300 g
Dietary Fibre	25 g
Protein	50 g

Nutrient	RDI		Nutrient	RDI
Vitamin A	900 µg		Biotin	300 µg
Vitamin C	60 mg		Pantothenic acid	10 mg
Calcium	1000 mg		Phosphorus	1000 mg
Iron	18 mg		Iodine	150 µg
Vitamin D	400 IU (10 µg)		Magnesium	400 mg
Vitamin E	30 IU		Zinc	15 mg
Vitamin K	80 µg		Selenium	70 µg
Thiamin	1.5 mg		Copper	2 mg
Riboflavin	1.7 mg		Manganese	2 mg
Niacin	20 mg		Chromium	120 µg
Vitamin B6	2 mg		Molybdenum	75 µg
Folate	400 µg		Chloride	3400 mg
Vitamin B12	6 µg			

1.3 Sample Activities

Packed Lunches

• Set up the scenario of preparing packed lunches.
• Focus on the question - How did you work that out?
• Use the first few questions as whole class activities with students discussing answers in small groups and reporting back. Good idea to use mini whiteboards, voting systems or simply asking other groups to agree/disagree with answers and different ways of working out or articulating how they did each question.

1.John likes apples but his sister, Ruby, only likes kiwi fruit. So when their dad does the shopping he has to work out how many to buy. He reckons that Ruby would need 2 kiwi fruits and John would need 1 apple each day.

a)So how many of each fruit would he need to buy for 5 days in school?
b) If he buys a saver bag of 8 apples, then how many kiwi fruits does he need to provide for the same number of days?
c) If he buys a saver bag of 12 kiwi fruits, then how many apples will he need to buy for John for the same number of days?

2. Jack and Amy's mum decided to replace their Saturday sweet treat with fruit. Jack chose strawberries and Amy chose satsumas. Mum decided that for every Satsuma that Amy had, Jack could have 3 strawberries.

a) How many strawberries does Jack get if Amy has 4 satsumas?
b) How many strawberries does Jack get if Amy has 7 satsumas?
c) How many satsumas does Amy get if Jack has 15 strawberries?

3. Susan likes pears and her brother Lee likes plums. Their mum decided that for every 2 pears that Susan had Lee could have 5 plums.

a) How many plums does Lee get if Amy has 4 pears?
b) How many plums does Lee get if Amy has 10 pears?
c) How many pears does Amy get if Lee has 20 plums?

4. A lunchbox has a packet of crisps that weighs 25g and contains 8g of fat per 100g of crisps. How much fat is there in 1 bag of the crisps?

A. 2g
B. 8g
C. 25g
D. 32g
E. 100g

5. Wheetos crisps are sold in 30g bags and contain 6g of fat per 100g of crisp. Quipo crisps are sold in 20g bags and contain 7.5g of fat per 100g. Which bag of crisp contains the most fat?

6. Most crisps contain about 80g of carbohydrate per 100g of crisp. Bread has about 40g of carbohydrate in every 100g. A slice of bread weighs about 50g, so what amount of crisps contains the same amount of carbohydrate?

A. 8g
B. 20g
C. 25g
D. 40g
E. 100g

7. A 125g pot of fruit yogurt had the following food label:

Energy	500kJ
Protein	5g
Carbohydrate	25g
Fat	1g
Vitamin C	1.25mg
Calcium	200mg

a) How much of each food type would there be in a 250g pot?
b) How much of each food type would there be in a 100g pot?

8. Get pairs of students to use some of the food labels in the appendix to compare amounts of carbohydrate or fat or protein. When you are sure they have some idea of proportionality ask them to prepare some questions for their peers. Get them to judge which are the best questions to demonstrate that they can investigate data and use proportional reasoning.

Food Cards

• Make some sets of food cards (see appendix).
• Give each pair of students the banana and the white bread food cards. Ask them to compare the similar foods with the banana and the white bread. Ask them to explain how they did this.

• Give each group of students 3-4 more food cards and ask them to find the food with the highest amount of carbohydrate. Ask them to explain how they decided this. Collect the 3 highest cards in and display so the whole class can see them
• Now ask them to find the food with highest protein content out of their remaining cards. Again ask them to explain their process and collect and display the cards.
• Next ask them to find the food with highest fat content out of their remaining cards. Again ask them to explain their process and collect and display the 3 highest cards.
• Ask each group to compare the food cards they still have with the high carbohydrate, high protein and high fat cards. How much more of each food group do the ‘high’ foods have?

The Washing Line

Set up 3 pieces of string as washing lines over about a 2-3m distance. Label one washing line CARBOHYDRATE, the next PROTEIN and the final one FAT. Make 3 copies of the food labels in the appendix. Get the students to work out the range from low to high values for each of the washing lines from the food labels. Mark the range and the midpoint with the values. Then get the students to place the labels on the washing lines with pegs or paperclips.

Ask students to work in groups to compare the foods on the washing lines. How would they describe the spaghetti in tomato sauce in terms of their amounts of carbohydrate, protein and fat?

Then ask them to pin up other labels (perhaps that they have brought in). How do these food compare with the ones they first placed up?

This activity can be developed to look at making changes in their diet. Get students to write out what they eat in a day listing each food or ingredient in a meal separately and ask them to use the details on the washing line to consider amounts of carbohydrate, protein and fat in each. How might they increase the protein/reduce the fat/spread the carbohydrate over more meals etc. in their diet for that day? What might they replace food X with if they wanted to keep up the same amount of protein but reduce the fat?

Testing for Vitamin C

This is an investigation. Read through p11-13 of the PRIMAS report which discusses how closed or open an investigation might be. Using the Fradd et al(2001) framework decide which level of inquiry you want your students to do. The amount of support you give at each stage will determine the level of inquiry and so plan this out carefully.

Demonstrate the effect of vitamin C on DCPIP by showing that a solution of vitamin C solution decolourises the blue DCPIP. Get students to test 2 or 3 of the juices you provide to practise the technique. Ask students to develop a hypothesis to test, and to investigate it systematically. Your classroom organisation may depend on the equipment you have available.

For each group of students:

Vitamin C solution, 1% See CLEAPSS Hazcard. CLEAPSS Recipe card recommends a concentration of 0.1%; this protocol suggests 1%. This solution is LOW HAZARD.

DCPIP solution, 1% (2,6-dichlorophenol-indophenol) is LOW HAZARD; see CLEAPSS Hazcard. CLEAPSS Recipe card recommends a concentration of 0.1%; this protocol suggests 1% so dissolve 1.0 g of dye in 100 cm^3 of water

Graduated pipette, syringe or burette.
10 pipettes
10 test tubes and rack
Fruit juice and squash samples

2.2.1.3 Assessing you students:

Using your Fradd et al(2001) framework, work out what evidence you would be looking for in each of the cells where students take control of the inquiry.

INQUIRY LEVEL	Questioning	Planning	Carrying out plan	Analyse data	Conclude	Report	Apply
0	Teacher	Teacher	Teacher	Teacher	Teacher	Teacher	Teacher
1	Teacher	Teacher	Student/ Teacher	Teacher	Teacher	Student	Teacher
2	Teacher	Teacher	Student	Student/ Teacher	Student/ Teacher	Student	Teacher
3	Teacher	Student/ Teacher	Student	Student	Student	Student	Student
4	Student/ Teacher	Student	Student	Student	Student	Student	Student
5	Student	Student	Student	Student	Student	Student	Student

2 Speed 1

2.1 Why teach this topic?

Everyday language uses these terms in relation to journeys, whether on foot, bicycle, car or 'plane. So there is relevance to pupils, and a wealth of opportunities to assemble and interpret these everyday associations. As the discussion extends to the problems of safety in travel, such topics as acceleration, braking distance and reaction times become significant.

A second reason is that the topic offers many opportunities for numerical work, quantitative reasoning, measurement, and use and interpretation of graphical representations. A particular reason for this is that everyone, and particularly those who study science, are trapped between everyday use of both Imperial and international unit systems, so such intra-conversion becomes necessary.

A third reason is that the concepts and measures involved pervade all parts of science, particularly in topics associated with the physics of motion. The links between force, acceleration and mass are fundamental, and studies of motion is straight or curved trajectories are necessary components in studies of the motions of objects ranging from the galaxies to electrons. More broadly, rates of reaction and rates of growth are other areas in which fluency with the topics concerned here is essential.

2.2 Background information

Several of the activities involve changing between different units and/or between different unit systems. The extent to which pupils are helped with these aspects of the task is up to the following data might be a guide:
I mile = 5280 feet = 1.610 km.
I m = 39.37 inches; 1 km = 3280 feet = 0.62 miles.
1 mile per hour = 1.47 feet per second.
Acceleration in free fall under gravity = 9.81 m per sec^2 = 32.2 feet per sec^2.
Thus for example, as 30mph= 44.1 ft per sec., so to stop in 1 sec means (44.1÷32.2) =1.37g

The activities give several opportunities for students to search the web for data. For example, several websites, e.g. Wikipedia, give extensive information about effects on the body of large accelerations and decelerations e.g effects depend on whether your body is aligned along, or perpendicular to, the direction of travel, and around 5g or more it can be dangerous

For the measurement of speeds in the classroom or lab. pupils will need metre rules and stopwatches. For exploring journey times, they will need local maps with clear indications of the scale of the map, and 30 cm. rules.

For the measurement of reaction times, metre rules and stop watches are required, but pupils have to use their measurements, of the distance a ruler fell in free fall under gravity if it starts from rest, to calculate the time of fall. They might be asked to calculate that for themselves, or given the following data :

Distance(cm.)	15	16	17	18	19	20	21	22	23	24
Time (secs.)	0.175	0.181	0.186	0.192	0.197	0.202	0.207	0.212	0.217	0.221
Distance(cm.)	25	26	27	28	29	30	31	32	33	34
Time (secs.)	0.226	0.230	0.235	0.239	0.243	0.247	0.252	0.256	0.259	0.263

2.3 Sample Activities

Activity A – how fast can you go?

Pupils can be asked to make measurements to find out:

How long does it take you to walk 5 metres, walking slowly, then walking quickly?

How far you can walk in 5 seconds, walking slowly, then walking quickly?

How can the time and the distance measurements be related to one another? What can you work out from the measurements?

In each case they could be asked to estimate the possible error in their result and then be asked – are your answers to the first two questions above consistent with one another?

Activity B – getting to school

(a) Make a measurement of the length of your journey from your home to your school.
How long does your journey take?
What can you calculate from these measurements? How does your result compare with the answers you worked out in Activity A?

(b) If you get to school in a car or in a bus, how long would it have taken you to walk (i) at a comfortable speed (ii) at your fastest speed (use the Activity A results).
A similar question can be asked for those who come by bicycle, whilst those who walk can be asked to estimate how long it might take by car.

(c) For any one of the results from parts (a) or (b), draw a graph of speed against time (i) assuming uniform speed (ii) representing what really happened What would a pair of graphs, one for walking, one for traveling in a car or bus, have in common if both were drawn for the same journey? What does the area under each of these graphs represent?

(d) For the two graphs used in part (c), draw the corresponding pair of graphs of distance against time.

Activity C – getting away from it all

Find out some data to enable you to draw a graph of speed against time for an aeroplane journey from London to New York. Your graph should represent the journey as accurately as possible.
Compare the values of acceleration that you could estimate from your graphs for activity B: how do these values compare with the acceleration for free fall under gravity?

Activity D – fast and slow speeds

Some motion can be so slow that it may not be noticeable. List some very slow speeds – you must give an approximate numerical value to every item listed. What is the slowest speed you, or others, can think of ? Similarly, list some very fast speeds – again with numerical values. What is the fastest speed you can think of ?

Some movements can be so slow that with a quick look you may not notice that there is any movement at all. Can you think of some examples? (Speed of growth of different plants, an object just heavy dense enough to sink in a very viscous fluid, rate of growth of your own hair or finger-nails)

A possible experiment here is to place a drop of a very viscous liquid (a thick honey or syrup might be suitable) on the flat part of a plate, then slowly tip up the plate until the liquid just starts to move. Then the plate can be supported at an angle just below the angle at which there is perceptible movement, and left for some time to determine whether movement has occurred, and if so to measure the speed.

Activity E - speeding up and slowing down

Here is a velocity-time graph for a driver's journey. Draw the acceleration-time graph for this journey.

The area under the line in the velocity time graph represents the distance travelled. What does the area under the acceleration-time graph represent?

This can be a tough one: label the first graph in mph – say up to 50mph, against minutes – say in the range 0 to 120 minutes – and then they have to choose a scale for accelerations – feet/sec^2 might do. A graph with two periods of acceleration and one for the final deceleration, with all three having different gradients, and with stretches of uniform speed in-between, would serve the purpose. Then pupils have to distinguish the positive and negative accelerations. The first graph should be straight lines only, so all accelerations are uniform, then the second is a set of rectangular blocks, and if the journey ends with the driver having stopped, the net area will be zero. The question can be made easier by giving hints about these issue. A sample graph is available).

Activity F – quick on the draw

(a) In Western films, it's the cowboy who can react the fastest who wins the duel, but reaction times matter in many more everyday situations. So how can you measure your own reaction time? Can you think of a way to measure your own, or one another's reaction time, given that typical values are around 0.2 seconds?

(b) Whatever may be the outcome of that discussion, pupils might then be asked to work in pairs to measure their reaction times. One pupil holds a one-metre stick vertically; the other stands with her/his lower arms horizontal so that the hands hold the bottom end of the sick; then that pupils opens her/his grasp a little so that the stick can fall freely between the hands.

Then, without giving any warning, the first pupil lets go of the stick: the second pupil grasps t he stick as quickly as she/he can to stop it falling, but because of the delay due to that pupil's reaction time, the stick will have fallen part of the way towards the floor. The pupils have to measure the distance fallen i.e. the distance from the bottom end of the stick to the point at which the hands grasped it to stop it falling. They can then be asked to work out how long it took to fall this distance – which gives the reaction time. Pupils will need to have the value of the acceleration for free fall under gravity: alternatively, the teacher may give them a table of values of distance against time for free fall over (say) 15cm. to 35cm.

(c) This work can be followed up by asking pupils to estimate how far they would travel in a bicycle between noticing a danger ahead and starting to swerve or apply the brakes: the same question can be asked about a car travelling at the speed limit on a busy town road.

Activity G – too many g's ain't good for you

An inventor claims that he has found a way to bring to rest a car travelling at 60mph within half a second. Some say this can be dangerous, for even if his body does not hit anything, the driver's internal organs can be damaged by the rapid deceleration involved. Is this a valid objection? To find out, use the web to find out about deceleration dangers for pilots and astronauts.

Activity H – straight or curved?

There is a distinction between velocity, which is the rate of travel in a straight line, and speed, which is total distance travelled whether or not it was in a straight line. Which of your measurements or estimates in the above activities were about velocity, and which were about speed ?

A driver travels from home to his friend's house and is accused of breaking the speed limit: he denies this, saying that he did not go the long way round, but went by a direct route. Is this a good argument?

The moon goes round the earth at an (approximately) constant speed but not at a constant velocity. What difference would it make if it went at a constant velocity? Why doesn't it do so?

3 Speed 2

3.1 Background:

Speed is one of the key concepts of science. Its foundation takes place during the teaching of kinematics, but the children have to understand the concept in other parts of physics, in chemistry (speed of reactions) and in biology (for example the motion of animals). In disciplinary dimension it can be understood as a vector (velocity) *or* as a scalar quantity (speed). In the tasks below the students interpret and calculate the speed on the basis of distance and time, thus developing their content knowledge, practice their investigation skills in science, carry out measurements and observations, record and analyze data, design experiments, identify variables and check their predictions. Proportional thinking stands in the focus of cognitive dimension of knowledge, the students predict and compare different speeds and explore the factors influencing speed. The social dimension of knowledge is also important, ie. speed is embedded into everyday contexts. The aspect of safe transport, the designing of transport in the individual's life and the world of sports also appear.

3.2 Learning environment:

The structure of the tasks are guided, ie. they give opportunity for inquiry-based learning in such a way that the students are motivated to learn and think individually with the help of questions and scaffolding. During the teaching mainly the group work methods are recommended, but there is opportunity for the whole class to discuss the definition of the problem, to formulate the research questions, evaluate the results and to draw the conclusions. In the case of some tasks individual reasoning and searching for solution might be an effective method. The experiments can be carried out with relatively simple tools partly in the classroom, partly out of the school. If the opportunities are given, the computerized measurement tools can be used as well (see *task 3*).

3.3 Sample Activities

<u>Activity A: Way to school</u>
<u>Research question:</u>

- How would you design your way to school?
- What data and aspects are to be considered during planning?
- How could you compare your possible routes and vehicles with one another?

<u>a) Measuring the speed of a pedestrian</u>
Planning/ execution:
(Tools available: stopwatch, long tape-measure)

- Design measurement methods to measure your walking speed!

Planning and guiding questions:

- How could you make the measurement more exact?
- What mistakes might occur?
- How could you identify the difference between the speed of hasty walking and strolling?
- Can you suggest a practical method to keep a relatively constant speed?

<u>b) Measuring travelling speed</u>

- Measure the average velocity of the vehicles (eg.: car, underground, bus, tram, bicycle) used during travelling to school!
- Include the data of each phase of the path and the forms of transport into a chart!

- Compare the distances and forms of transport on the basis of your charts!

Planning and guiding questions:
- How could you tell the length of each phase of the paths?
- What traditional or modern tools could you use?
- What advantages and disadvantages are there of the possible tools and methods?
- How could you design the chart in such a way that
  - each phase of the paths are transparent,
  - every measurement data and calculated result appears,
  - the spatial location of each phase is clearly identifiable?

Discussion, conclusions:
- What factors influence the average velocity of each form of transportation?
- In the case of which form of transportation are the fluctuations of speed the biggest?
- How could you decide which form of transport is the fastest?
- What factors do you take into consideration while designing your route and choosing the paths and forms of transport?
- Could you find an alternative route/ form of transport?
- What advantages and disadvantages of the alternative routes have?
- What further communal and global factors might influence your choice?

<u>c) The estimation and comparison of speeds</u>
Every morning four students walk to the same school nearby. Kate and John live in the same house, therefore, they cover the same distance, but not within the same time. Peter lives further, and arrives at the school at a longer period of time. Mary lives the closest to the school and her route takes the shortest time. All the four students measured the length and duration of their way to school. The data are included in the chart below:

	Kate	John	Peter	Mary
Distance *(m)*	1600	1600	2400	1400
Time *(mins)*	26	24	28	14
Speed *(m/sec)*				

- Which student was the fastest?
- Using estimation align the four students on the basis of their speed!
- Prove your estimations with calculations!

<u>Activity B: Speed and safe transport</u>

<u>Research questions:</u>
- How safe is transportation by car?
- How much risk of an accident does traffic mean?
- How does the choice of speed influence the safety of transport by car?

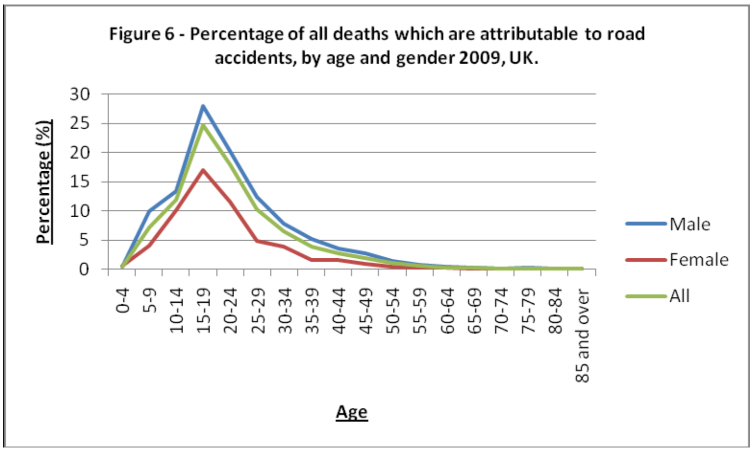
<u>a) Measuring the speed of transport:</u>
Planning/ execution:
(Tools available: stopwatch, long tape-measure)

- Design a measurement method for measuring the speed of cars running on the road near the school!
- Make a chart from the measurement results!
- Provide the data with different measures!
- On the basis of what aspects can the data be analyzed?

Planning, guiding questions:
- What speed can be measured with the chosen method, how is it different from the laser method the police use?
- How shall the measurement be changed so that you can calculate the average velocity of the transport?

Discussion, conclusions:
- Did the drivers keep the speed limits?
- Can the examined part of the road be regarded safe from the viewpoint of the pedestrians?
- What dangers did you experience?
- What advice could you suggest in order to increase safety?

b) Graph analysis:
- What relationship does the graph present?
- Identify the age group which is the most endangered in the respect of the risk of accidents!
- How could you explain the differences between the age groups?



http://www.rospa.com/roadsafety/default.aspx

c) Data analysis:

- What conclusions can you draw on the basis of the chart below?
- What additional data would you need in order to be able to tell which form of transport means the biggest and the lowest risk of accident?
- Estimate the missing data!

Mortality statistics in accidents (England – Wales, 2011)

Total mortality in accidents	17 201
Total mortality in transport	1 970
Car (driver, passenger)	808
Motorcycle	347
Pedestrian	153
Cyclist	96

http://www.guardian.co.uk

Activity C: Speed and braking distance

Research question:
What factors determine the stopping distance of cars?
How does the starting speed influence the car's braking distance?

a) Stopping and braking distance

Decide on the basis of data and pieces of information on the a braking distance calculating site:

- What is the difference between braking and stopping distance?
- Which are the fixed, independent and dependent variables in the case of calculating braking distance?

Braking distance calculator: http://forensicdynamics.com/stopping-distance-calculator

b) Measuring braking distance

(Tools necessary: toy car, tape-measure, sand, rough rubber; for the slope: thick books, hard cardboard or wooden table; for measuring the speed: stopwatch or instrumental measure tools, eg.: webcam system)

Planning/ execution:

- Design a measurement system using the available tools!
- In order to settle the starting speed of the car, use a slope, the height of which can be varied!
- Measure the speed of the car coming down from the slope, eg.:
  - on the basis of time necessary for covering a given distance (eg. 1m), or
  - with the help of light gate, or
  - with the use of Webcam Laboratory, *(http://www.webcamlaboratory.com/kinematics.php)* or
  - any other way
- Construct an adequately long track for the stopping of the car with
  - a few mms thick sand layer, or
  - a rough rubber
- Record the data of measured speeds and braking distances!
- Illustrate the length of the braking distance in relation to the speed!

Planning, guiding questions:

- What is the optimal height of the slope?
- How can you keep the thickness of the sand at a constant measure?
- What is the optimal number of measurement at the given speed?

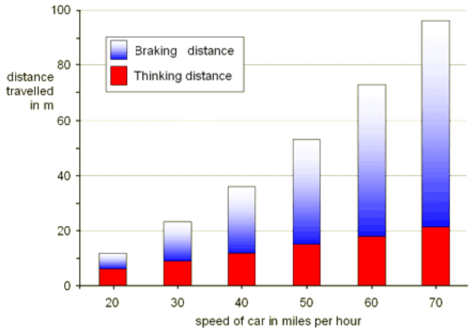
Discussion, conclusions:

- On the basis of the graph what conclusion can be drawn in connection with the relationship of the speed and the braking distance of the car?
- On the basis of the above stated relationship argue why is speed limited more strictly in a populated area than on the open road?

c) Graph analysis (*after finishing part b) of the task*)

On the basis of the graph answer the following questions:

- How does the length of reaction time change with increasing speed? *(Compare it with the braking distance!)*
- What is happening during the reaction time, why is it necessary for the driver?
- What factors might cause the increase of the reaction time?
- What regulations try to avoid accidents originating from this?



http://www.bbc.co.uk/schools/gcsebitesize/science

Activity D: Record keepers

The results of the running competitions during the a 30th Olympic Games in 2012 in London:

Name of the Olympic Champion	**Country**	**Distance** (m)	**Time** (min:sec.)
Usain Bolt	Jamaica	100	9.63
Usain Bolt	Jamaica	200	19.32
James Kirani	Grenada	400	43.93
David Lekuta Rudisha	Kenya	800	1:40.91

- Illustrate the results of the four runners in separate distance-time graphs!
- Link the points with a line! Choose the times necessary for the covering of 100 meters and indicate them in the graphs, then link these points with a line!

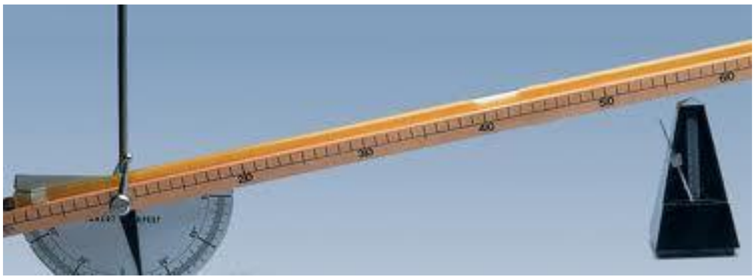
Questions:

- What is the difference between the graphs?
- What shape is the line connecting the four points?
- What can be stated about the speed of the runners on the basis of the graphs?
- What result would have Usain Bolt achieved if he had run 800 meters with his average velocity of the 100 meters?
- Why is the above case impossible?

Activity E: Uniform Linear Motion and Uniformly Accelerated/decelerated Linear Motion (for ages 12-14)

The investigation of uniform linear motion

Task: the investigation of the characteristics of uniform linear motion with Mikola tube and making a distance-time graph.


(Mikola tube)

- The introduction of the investigation process. The metronome ensures the equal time sequences, the children label the actual position of the bubble with a chalk. They measure in three different inclination angles. Two methods of data recording are possible: either the children record the distances from the starting position of the bubble to the end of each click, or they record the distances between two clicks.
- The preparation of the chart representing the investigation data.
- Carrying out the investigation in group work, with the help of the teacher if necessary.
- The preparation of the distance-time graph on the basis of the investigation chart with the help of the teacher if necessary.
- The analysis of the distance-time graph.
- How does the speed of the bubble change if we increase the angle of the tube?

(As the graph has a maximum, there is direct proportion only in the case of small angles (eg. 10°, 15°, 20°).)

- How long distances does the bubble come within the same time intervals?

1) Track pattern

Task: the recording of the track pattern of an object in motion, for example a thrust toy car, and the implication of the characteristic of the motion on the basis of the track pattern.

- Tools: Ruler, chalk, pencil, exercise book, watch and a toy car on the side of which an empty can is tied, on the bottom of which there is a tiny hole, so that the water will uniformly drop. The children shall take this down to a blacktopped yard where they push the car and measure the distances between two drops.
- The preparation of the chart representing the investigation data. The unit of time is second and the unit of distance is centimeter.
- The negotiation of the results.
- What was the toy car's motion like? How do we know this?
- The graphic representation of the motion.

- The analysis of the graphs of the two tasks, ie. the investigation with the Mikola tube and the investigation with the toy car.

The Relationship Between Distance-time, Speed-time and Acceleration-time

Task: Preparation of graphs on the motion of a tram between its two stops, making the distance-time, speed-time and acceleration-time graphs.

In order to simplify the task, the tram line is straight, the vehicle does not turn and its acceleration is constant during the motion.

The track pattern of the motion looks like this:

Data

- the distance between two stops: 500 meters
- acceleration of the tram: 0.5 m/s^2
- the duration of the acceleration: 20 seconds then it goes with steady speed and then slows down again for 20 seconds

Solution

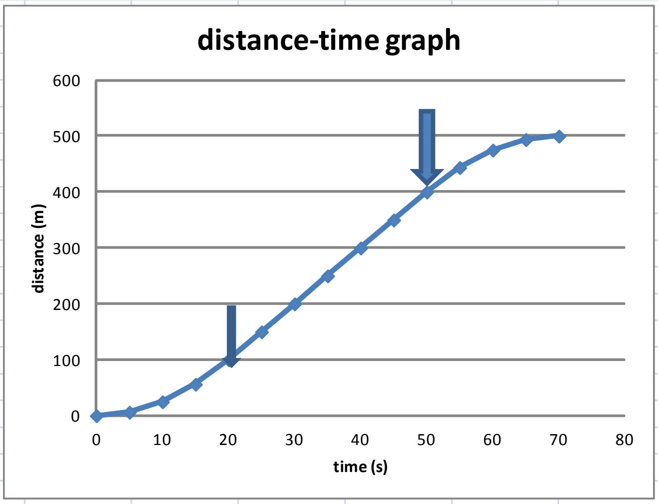
We can calculate the speed like this: $v = a \cdot t = 0.5\ m/^2 \cdot 20\ s = 10\ m/s$. The tram goes 100 m in 20 s. It decelerates for 20 s as well and goes 100 m again. So, the tram goes 300 m with 10 m/s steady speed in 30 s. The tram goes for 70 s altogether.
When the tram accelerates, the distances making in the same time, get longer. The ratios of the distances are 1:3:5:7. Therefore the formula for the distance is: $s = a/2.t_{gy}^2$
The distance gets evenly longer: $s = v_{max} \cdot t_e$.
When the tram decelerates, we can calculate the distance like this: $s = 400\ m + v_{max}.t_l - a/2.t_l^2$

Time (s) – distance (m) chart. We choose 5 seconds as a unit of time.

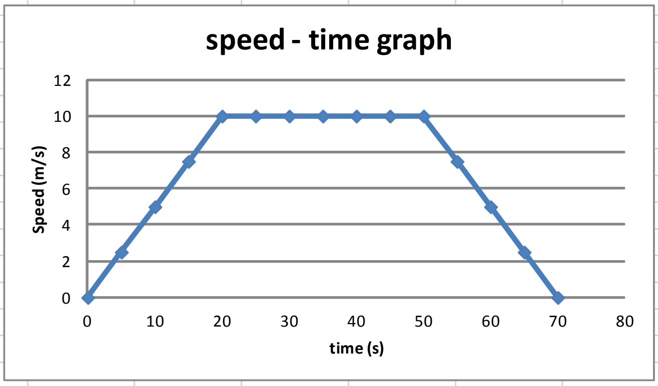
The unit for distance means the distance covered within the first time unit –in this case 6.25 meters. This is the unit in relation to which we compare the distances covered during the other time units. During acceleration 1:3:5:7, during steady speed it is 8, during deceleration it is 7:5:3:1.

Time of measurement (s)	Distance measured from the starting point (m)	Distance between the points	Unit for distance
0	0		
		6.25	1
5	6.25		
		18.75	3
10	25		
		31.25	5
15	56.25		
		43.75	7
20	100		
		50	8
25	150		
		50	8
30	200		
		50	8
35	250		
		50	8
40	300		
		50	8
45	350		
		50	8
50	400		
		43.75	7
55	443.75		
		31.25	5
60	475		
		18.75	3
65	493.75		
		6.25	1
70	500		

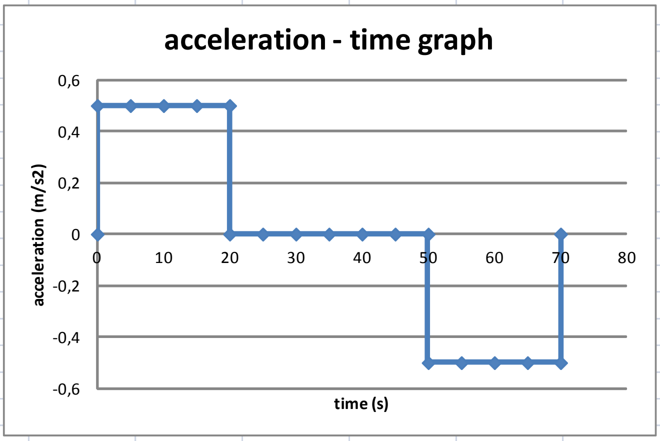
time (s)	distance (m)	
0	0	
5	6,25	
10	25	
15	56,25	acceleration
20	100	
25	150	constant speed
30	200	
35	250	
40	300	
45	350	
50	400	
55	443,75	deceleration
60	475	
65	493,75	
70	500	



time (s)	speed (m/s)	
0	0	
5	2,5	
10	5	
15	7,5	acceleration
20	10	
25	10	constant speed
30	10	
35	10	
40	10	
45	10	
50	10	
55	7,5	deceleration
60	5	
65	2,5	
70	0	



time (s)	acceleration (m/s2)
0	0
0	0,5
5	0,5
10	0,5
15	0,5
20	0,5
20	0
25	0
30	0
35	0
40	0
45	0
50	0
50	-0,5
55	-0,5
60	-0,5
65	-0,5
70	-0,5
70	0



The graph of the motion of tram line 4

- Analyze the graphs and indicate in the first graph where the tram accelerates, where it goes with a steady speed and where it slows down.
- In the second graph describe the changes of the tram's speed.
- In the third graph indicate how long the tram accelerates, how long it goes with a steady speed and how long it slows down.

4 Reaction Rates

4.1 Why teach this topic?

Rates of reaction is a topic that has relevance in everyday life from cooking, to taking medicines to aging! Usually this topic in investigated in schools using tetheffect of acids on marble chips – both of these materials are mainly unfamiliar to the students when they are starting their studies in chemistry. Therefore the context as outlined below of effervescent vitamin C tablets was chosen as it familiar to the students and is non-threatening in that students can handle these materials without fear of burns or acids spills.

Using a context that is known to the students can increase interest and motivation in the subject matter. In this series of activities, effervescent vitamin C tablets can be used to distinguish between solubility and reaction and also to discuss ideas of the factors that can affect the reaction rate, particularly surface area and temperature. The following is a number of activities that can be used with students to develop their understanding of key concepts underlying rates of reaction while also developing investigative and inquiry skills.

These activities are suggestions only and can be used in a variety of ways to suit the particular class grouping.

Key areas:

Concepts: factors that affect reaction rate – including temperature, concentration of reactants, surface area of reactants

Reaction of acids with carbonates, release of CO_2

Investigative skills: Planning an investigation, identifying variables (relevant and irrelevant), handling complex system to reduce number of variables

Determining relationship between variables

Determining causality

Reasoning: Causality, proportional reasoning, (graphical interpretation)…

Context: **effervescent vitamin C tablets**

Required: effervescent Vit C tablets, Na_2CO_3, citric acid, ascorbic acid

Apparatus to trap CO_2 (funnel, tubing, lime water), range of beakers, measuring cylinder, deionised water, pH probe (universal indicator paper)

4.2 Sample Activities

Initial Questions:

- What is happening when I place a tablet in water?
- What is present in the tablet that may be causing this?

Students can do this themselves in groups and should make note of their observations which may include: see bubbles, movement of tablet, 'dissolving of tablet', 'fizzing sound'….

From reading the packet, there is Na_2CO_3, citric acid and ascorbic acid present

- Encourage the students to come up with their own question to investigate

Possible investigative questions:

- What gas is present in the bubbles and where has it come from?

  Students can collect the gas formed and check if it turns lime water, combustion characteristics, etc. (distinguish it from oxygen)

  Students can determine the combination of reactants that will produce CO_2 e.g. addition of any one of Na_2CO_3, citric acid or ascorbic acid to water on there own does not liberate gas to the same extent, but addition of both citric and ascorbic acids to Na_2CO_3 produces CO_2.*

  Important here to distinguish between dissolving and reaction e.g. each of the substances Na_2CO_3, citric acid and ascorbic acid will dissolve in water but it is only when the carbonate is combined with the acid that reaction occurs (as seem by formation of new substance CO_2)

- Can we measure the rate of this reaction?
  (i) Students can devise a way of measuring the time for the total reaction when tablet is dropped into water (e.g. by measuring time for bubbles to stop – but decision has to be made when is the last bubble! – devise a statement such as 'when there are no bubbles for 3 secs' or such like; by measuring the time taken for the tablet to move from the bottom of the container)
  (ii) Students can then devise experiment to determine the total amount of CO_2 produced from one tablet
  (iii) Students can then devise an experiment to determine the amount of CO_2 produced with time from one tablet

  Reproducibility – variation within the class group or variation within students own experiments

- Quantify the rate – is the rate of release of bubbles the same all the time?, drawing graph of e.g. amount of CO_2 released vs time; how can the rate be determined from the graph – is the rate constant, where is it fastest/slowest (determining slope at different time intervals)

- Can we change the rate of this reaction? Design a series of experiments to investigate their hypotheses.

  Students could suggest **

    - using hotter water /temperature
    - using different amounts of tablets /concentration
    - changing the amount of water used per tablet / concentration

With more advanced chemistry group, it is interesting to investigate the rate of reaction between Na_2CO_3 and citric acid and compare to that between Na_2CO_3 and ascorbic acid. Then to suggest explanation of why citric acid is added to these tablets (Na_2CO_3 reacts with citric acid first to release carbon dioxide leaving solution of ascorbic acid) – leading to further questions in terms of the amount of citric acid required, limiting reagent, which one is in excess – are more bubbles produced if more citric acid added/more ascorbic acid added/ more Na_2CO_3 added.

- Do all these effervescent tablets have the same rate of reaction?

  Students could suggest using different products with varying amount of Vit C (ascorbic acid).

  Can they interpret the labels to explain the rates of reaction determined.

  Some of these tablets contain 1000mg of Vit C, well in excess of the recommended daily allowance – so how many tablets should you take to have your RDA?

The Fradd et al (2001) Framework could be used to note evidence you would be looking for in each of the cells where students take control of the inquiry (attached at end).

INQUIRY LEVEL	Questioning	Planning	Carrying out plan	Analyse data	Conclude	Report	Apply
0	Teacher	Teacher	Teacher	Teacher	Teacher	Teacher	Teacher
1	Teacher	Teacher	Student/ Teacher	Teacher	Teacher	Student	Teacher
2	Teacher	Teacher	Student	Student/ Teacher	Student/ Teacher	Student	Teacher
3	Teacher	Student/ Teacher	Student	Student	Student	Student	Student
4	Student/ Teacher	Student	Student	Student	Student	Student	Student
5	Student	Student	Student	Student	Student	Student	Student

4.3 Assessment

* Students should devise a matrix of 3X4 to determine all the possible combinations of the 3 reagents with water

** Designing the experiment – students should have considered –

their hypothesis,

variable that they will measure, variable that they can change, variables that they must keep constant,

set up of the experiment (including necessary equipment)

manner of recording results.

Questions focussed at Scientific Concepts:

Q.1 Marble chips reacts with acid to produce CO_2 gas. Marble is available as a board, large lumps and as ground powder. Suggest, with explanation, which forms of marble should be used to generate CO_2 most quickly.

Q.2 Vinegar is often used to clean surfaces at home. If you have a marble ($CaCO_3$) worktop, would you use vinegar – explain why/why not.

Q.3 Discuss a reaction that you know and the affect that temperature would have on it

Q.4 Give a set of data – e.g. amount of CO_2 produced vs time in a given reaction;

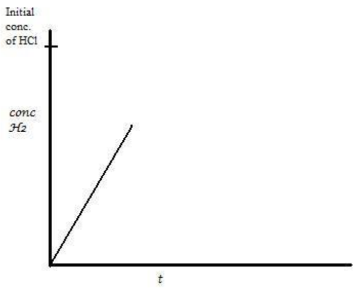
represent the data on a graph,

describe what the graph tells you – in terms of where the slope is greatest and slope least.

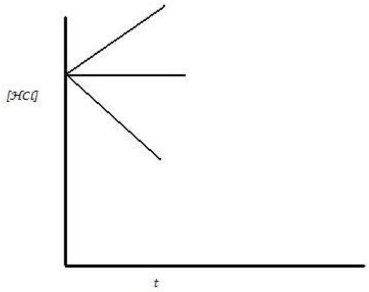
(advanced) Draw on the graph a line showing the change in concentration of Na_2CO_3 over this time

The following questions could be applied directly to the experiments carried out or can be given within a different context of the Mg plus HCl reaction.

Q 1 (i) In the reaction of HCl with Mg to form H_2 (reaction HCl + Mg → $MgCl_2$ + H_2), the change in concentration of H_2 is shown on graph (A). From the point shown, draw in how the HCl concentration would change over the same time
(Alternative question - select which line in graph B shows how the HCl concentration changes over the same time).



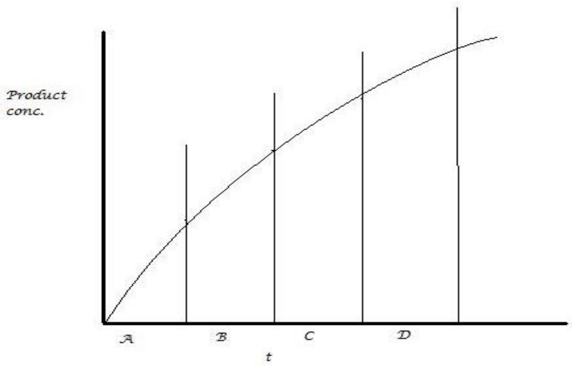
Graph A



Graph B

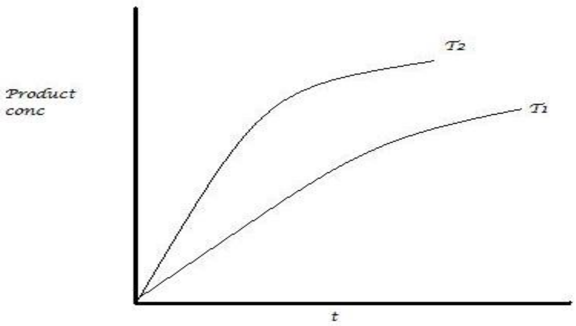
ii) If the reaction continued until all the Mg was used up, extend the graph (A) to show how the H_2 concentration would change.

Q2. In a particular reaction, the concentration of product is shown (graph C). During which time interval (A – D) is the rate of reaction the fastest <u>or</u> put rate of reaction in order from fastest to slowest.



Graph C

Q3. For the reaction shown in Graph D, at which temperature is rate of reaction the highest/ slowest? Explain your answer.



Graph D

Appendix 2: Amended Materials for Teacher Workshop

A detailed plan to help workshop organisers in Ireland make their teachers aware of on-going and checking non-diagnostic assessment opportunities is given overleaf. Note that the aim was not to provide teachers with a tick-box model for designing inquiry-based classes, but to illustrate the wealth of opportunities that are there.

Lesson sequence	Assessment Element	Individual/ Group	'Good'	'Average'	'Poor'
1. Lesson opening Effervescent vitamin C tablet – teacher puts it in water and asks group to observe what happens. Teacher leads a group discussion and students call out what they see e.g. fizzing, colour changes, bubbles, tablet disappears, etc[1].	[1]observation	Whole group assessment	Discusses and compares what other members of group observe.	Make a number of relevant observations as statements(eg bubbles produced etc)	Making irrelevant Observations "eg "water bubbling"
Students encouraged to make inferences[2] from observations, such as: bubbles, therefore gas formed, therefore new products, therefore reaction occurring. Tablet does not just dissolve, a reaction is happening. Conclusion – reaction occurs, gas as a product of reaction	[2]forming coherent arguments	Individual or group	evidence + reasoning + conclusions, e.g. reaction is happening as can observe bubbles which shows that a gas is produced	evidence + (reasoning or conclusions), e.g. production of bubbles is evidence of a reaction	observations only, e.g. I see bubbles

2. Setting the task Teacher gives question: "I'm in a rush in the morning and want the vitamin drink to be ready to drink as quickly as possible; what can I do?" Groups discuss how to do this; for example: - Temperature of water - More water/less water - Surface area/breaking up tablet Groups must elaborate on why they have chosen a particular method. Students write down how they are going to speed up reactions and explain why[3]. Consider having all things go on at once and groups report back to each other[4].	[3]**diagnosing problems** Forming testable hypothesis/ Explanation [4]**Coherent arguments** Expressing clear explanations why it is appropriate method.	Small group assessment Student assessment of others work	Explains input variable and control variables + why (plausible explanation)	Recognises input variable based on prior experience	List variables and needs help to select a suitable input variable

Appendix 3 Pilot Materials Evaluation Sheet

Reporting Back on Inquiry Activities

1. Which activity/activities did you try and with which class?

2. Which aspects of inquiry did you hope to engage your learners in through the activity and how successful/difficult was this?

3. How did your learners respond to doing this/these activities?

4. What did they learn through doing this/these activities?

5. What did you assess and did you manage to assess some or all of your learners through the activity/activities?

6. What would you change if you did this activity again?

NAME: SCHOOL: