Learn Chemistry

Oil Sands Process Water: When diamonds are not forever!

Resource Overview

This resource was produced as part of the National HE STEM Programme

National HE STEM Programme

RSC | Advancing the Chemical Sciences

www.rsc.org/learn-chemistry

CONTEXTUAL NARRATIVE FOR TUTORS

Project Summary

Currently much of the world still relies on crude oil as a major source of energy, but the crude oil reserves that are easiest to produce are rapidly diminishing. Whilst some economies of the world are slowly turning to other sources of energy, there is still great interest in exploiting less conventional oil reserves. The oil sands of Alberta, Canada represent the third largest proven crude oil reserve in the world, next to Saudi Arabia and Venezuela[2], and the USA is building pipelines to transport the oil throughout North America. However, unlike most crudes, the Canadian oil has been degraded by bacteria and needs to be separated from the sand by washing it with alkaline water. This produces several barrels of waste water for every one barrel of crude and so far up to a trillion litres of oil sands process-affected water has been produced and stored in large lagoons, known as tailings ponds. This water is toxic to a range of organisms including some fish and birds, so the Canadian government wants scientists to find out what is causing this and how to remove it.

Learning opportunities: The present problem-based learning resource is aimed at helping students to develop approaches which might lead to the discovery of what some of these pollutants are, what properties they might have, to attempt to draw them using computer packages and to use these drawings to calculate their likely toxicities using modern chemical sciences methods and computer models. The students will also have an opportunity to interpret spectral, chromatographic and other analytical data.

The present project entailed proposed production of material for the priority area 'Water & Air', which focuses on the challenges that exist in the areas of drinking water quality, water demand, waste water, contaminants, air quality and climate and more particularly on the RSC Roadmap (http://ww.rsc.org/ScienceAndTechnology/roadmap) sub division **'**Wastewater and Contaminants', which involves students in learning about researching the measurement, fate and impact of existing and emerging contaminants[1].

Role of the Tutor

The criteria set by the RSC required that the work align with the definition of Context/Problem-Based Learning made by Savery[3]. Savery defined Problem-based learning as an instructional, learner-centred approach that empowers learners to conduct research, integrate theory and practice and apply knowledge and skills to an *ill-structured problem*. Selection of an ill-structured, often interdisciplinary (or multidisciplinary) problem and the involvement of a tutor, who guides the learning and conducts a debriefing at the end, is considered by Savery to be critical to the success of the approach. The use of the present resource by the tutor and students therefore assumes that the characteristics of PBL discussed by Savery, apply.

The resource is planned to be somewhat open-ended and assumes the active involvement of a knowledgeable, experienced tutor. It does *not* attempt to provide detailed instructions or 'answers' to every question, which may arise during the exercise. In 'real-life' research and industrial problems, final 'answers' are often elusive; what it is important is for the learners to develop a problem-based approach which will advance their knowledge of the issues towards a given goal. The tutor can aid this, particularly where a sound background knowledge of chemical principles is required of the students (e.g. what is pK_a and how is it measured?) but which may be lacking. To some extent, both students and tutor are learners in this kind of exercise.

Assessment

It should be assumed that the principles outlined by Savery[3], apply. Thus, self and peer assessment should be carried out at the completion of the problem (which can effectively be considered a curricular unit for present purposes). According to Savery the essential characteristic of the assessment should be reflection on knowledge gains. He states that "Students are responsible for the content in the curriculum that they have "covered" through engagement with problems and need to recognise and articulate what they know and they have learned"[3].

The opening session based on a quiz show model using interactive technology such as Turning Point® or similar provides an opportunity for group feedback and assessment (e.g. via the software which automatically acquires data on numbers of correct answers etc). Analysis by the tutor, of the correct and incorrect answers to the questions posed in this session will give a general indication of the depth of reading and pre-searching made by the student body as a whole.

Much of the data and information to be obtained by the students (it is suggested) might be compiled in spreadsheet format (e.g. Microsoft Excel® or similar). It is suggested that these are scrutinised by the tutor at regular intervals, possibly conveniently at the end of each learning session. This can of course be achieved by students submitting their worksheets electronically to the tutor.

Towards the end of the project, students are required to give individual presentations and justifications of the acidic organic pollutants, which they have suggested. This presents additional opportunities for individual assessments of the oral contributions of each student, if required.

As a reflective exercise, the beginning of the closing plenary session is a repeat of the opening quiz show model using interactive technology such as Turning Point® or similar. A reflective opportunity for group feedback and assessment thus presents itself from an analysis by the tutor of the correct and incorrect answers to the questions posed in this session.

Finally, a full professionally written report of the whole exercise is to be made by each student and assessed as appropriate.

Software pre-requisites

A significant proportion of the time to be spent on this resource requires access to computers. It would be appropriate for all sessions to be timetabled in rooms where are sufficient computers, ideally for each individual.

Turning Point® (http://www.turningtechnologies.co.uk/) or similar software is required in order to make the introductory session interactive.

ChemSketch software (http://www.acdlabs.com/download/) is needed for drawing structures of chemicals and for generating SMILES notations and names of chemicals.

ECOSAR software (http://www.epa.gov/oppt/newchems/tools/21ecosar.htm) is needed for calculating the predicted toxicological effects of the chemicals on various biological end points.

Tutor Guidance

Session 1. (60 minutes) Introduction to the problem.

In advance of Session 1, and in order that they may answer the ten quiz questions, or at least make a reasonable informed attempt, students should be asked to read information about oil sands production and processing. The following web sites may be suggested by the tutor by an e-mail memo in advance, but students should also be directed to conduct their own search on the search term ‘Oil Sands’ in preparation for Session 1. It should also be made clear that students will need this background knowledge in order to carry out the problem-solving elements of subsequent sessions.

Suggested websites:

http://environment.alberta.ca/apps/osip/

http://www.shell.com/home/content/aboutshell/our_strategy/major_projects_2/athabasca/?gclid=CMKujsbXmqwCFQJO3godd28XQg

http://en.wikipedia.org/wiki/Oil_sands (all above last accessed 3.11.11)

http://www.guardian.co.uk (search ‘oil sands’ for information on many related issues)

A slide presentation is provided in order that the tutor may outline the nature of the problem to the students in a problem-based, interactive manner. It is suggested that the slides provided be converted to a ‘clicker-based’ interactive presentation using Turning Point® (http://www.turningtechnologies.co.uk/) or similar software so that the quiz is more instructive and entertaining for students and so that histograms of the answers are produced. Answers given in the presentation provided contain information, which may be used to encourage students to engage in further reading (e.g. references to general scientific articles in *Nature* and more specific research papers). This may also inform the quiz in the final session, if this approach is adopted.

Sessions 2-4.

The resource is then further developed as a series of instructions and encouragements, plus additional data, provided in the form of Power Point slides (the latter allow flexibility to the tutor). Two versions are available, one with student and one with student plus tutor notes (the latter indicated with a ‘T’). Font sizes deliberately change in an attempt to keep the number of slides small whilst maintaining clarity. However, tutors may change these as they see fit. EI mass spectra of 12 unknowns are provided in Session 4 . More spectra can be supplied on request: chemistry@plymouth.ac.uk.

Students are encouraged to make an on-going, progressively improved, spreadsheet of all of the data that they can assemble in their attempts to address the problem. As with any storage of data in this way, students should be encouraged to make back-up copies of all of their data.

The division into sessions 2-4 is entirely arbitrary and intentionally somewhat unequal in length. Most tutors noted that they adapted the sessions to fit their own needs and this is entirely appropriate, but takes time. Tutors can subdivide the work as required or as judged from the rate of progress and the experience and abilities of the students. Some further guidelines on this are given with the slides but each tutor should divide the material as they deem appropriate.

Session 5

Session 5 comprises a repeat of the initial quiz questions (Session 1) and may be followed by a plenary Power Point-style lecture, once the final reports from the students have been handed in**.** The latter lecture can be compiled from the current research literature by the tutor in order to keep pace with more recent developments, or indeed made more or less specific as required. One tutor involved in the trialling of the resource felt the plenary lecture provided was too focussed on one research approach to the problem so this has been omitted but is available on request to chemistry@plymouth.ac.uk. Other approaches and plenty of research material are available from worldwide web sources (some suggested websites are given as references in the slides).

Intended audience

The resource was developed with second year honours undergraduates in chemistry in mind. However, it is difficult to gauge exactly the level of audience for whom this resource might prove useful. A degree of knowledge is expected in fundamental chemical concepts such as acidity (e.g. pK_a) and some prior knowledge of analytical techniques such as infrared spectroscopy and mass spectrometry is also desirable. However, where this knowledge does not already exist, students can be encouraged and allowed time to seek such information as part of the exercise. It is hoped that the desire to solve the problem will prove sufficiently inspiring to encourage the self-learning needed to make a reasonable attempt to learn about the techniques needed and this certainly seems to have been the experience of most students who took part in the pilot phase (some details are given below). It may prove possible to extend use of the resource to undergraduates in other subjects, particularly environmental chemistry or environmental science.

Feedback from piloting

Tutor and Student feedback:

One of the two tutors who piloted this resource found that it provided a very useful learning experience for their students (e.g. “Overall I was very happy with the content of the PBL”) whilst another felt the approach was too specific to a given area of research and that “ the author has adopted a very esoteric approach to solve a complex analytical problem with very little actual pulling together of analytical data”. The latter also felt that “expecting students to be competent with a particular chemical structure drawing program essentially within a PBL session was not realistic. Prior experience in the use of this software would be useful”. However, the latter tutor did not have computers available for teaching; ad hoc arrangements had to be made and these were not adequate for the proper use of the resource. Essentially, the trialling in the latter institution was not successful because of the short time scales involved. Adequate preparation time should be allowed in future uses of the resource. This tutor indicated this unavailability of PCs had a detrimental effect on the student engagement and likely perception of the material. Revisions to the resource were made following trialling and a greater attempt made to integrate the data.

It was assumed (and is hereafter) that adequate personal computers would be available to each student for successful implementation of this resource. In addition, tutors should expect to invest considerable time in advance when preparing to tailor this resource to their own needs.

Some tutors chose to use an interactive voting system that their institution supported rather than Turning Point and found this worked well. Also, instead of ChemSketch some tutors successfully used ChemBioDraw (again software available under licence to their university). Some arranged for ECOSAR to be downloaded for use on the university-networked computers. In addition, there were a number of journal articles referred to within the resource that the students need to refer to. Some tutors found it useful to collect all of these together in advance and to make these available via a VLE environment to any students who had trouble finding them themselves. However, it is a very useful part of the problem-based approach for students to find such materials themselves, provided they have sufficient time and resources available to them.

Some tutors found it necessary to modify the structure of some of the sessions so that they were more equal in length and this was quite time-consuming. A further tutor also needed to spend quite a bit of time planning their own schedule and that of the students. Thus, it should be emphasised that the suggested timeline is only indicative and should be modified where necessary.

Tutors stated that the students commented that this “was an area of chemistry that they had not encountered before and that all of them felt that they had enjoyed working on this particular scenario. There were one or two issues with working within teams but the majority of them enjoyed it”.

That said, one tutor stated that “as a problem based learning exercise the dependence on individual drawing of structures on computers precluded any sensible team working. Though this would work better if the students were using laptops.” It was always the intention of the resource developer that the students would be provided with computers.

Finally, tutors recognised that the role of the tutor and style of teaching, in general, were somewhat different to those normally associated with traditional teaching and, as such, some tutors might benefit from would require some investment of time and possibly further guidance or training. It was also suggested that alternative assessment strategies might be used, including the use of both group and individual reports.

References

1. http://www.rsc.org/ScienceAndTechnology/roadmap/
2. http://www.energy.alberta.ca/OurBusiness/oilsands.asp
3. Savery J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *The Interdisciplinary Journal of Problem-based Learning*, **1**, 9-20.

Student feedback comments of C/PBL resources (composite from two resources evaluated)

Experiences of C/PBL

“It was good because it was something I'd have never really thought chemistry played a big part in and it allowed me to broaden my horizons and think how chemistry is used in other areas which you wouldn't initially think of. It also allowed us to see and understand some of the other spectroscopic methods, instead of the more common IR and NMR spectroscopy.”

“Overall the exercise was entertaining and very interesting as it gave me insight into other areas of chemistry past the obvious in pharmaceuticals and the petroleum and chemical industries. It was nice to work as part of a team as opposed to the mainly individual work of university.”

“I enjoyed taking part in the course as it was very engaging and required us to work as a team, an experience which is invaluable in future life. However, I did feel the problem could have had a wider range of chemistry in it so the students taking part in the course could gain the most out of it.”

“I thought the experiment was great and I enjoyed the whole experience. I would definitely recommend it to other students.”

“In my opinion the context/problem based learning format was extremely useful in terms of learning, but also understanding what I was learning more effectively.”

“Overall, the experience of the PBL task allowed a relaxed investigation into an area that would not usually be explored.”

“Personally I feel that the context/problem based learning is a useful skill which I have acquired, which will continue to help my learning throughout my degree.”

“On a non-scientific level, I have learnt a great deal about problem-based learning, a way of learning that I hope to be taking part in during future education.”

“I believe that incorporating PBL into routine course learning would be very beneficial to any student.”

“I think a combination of information delivery in lecture form and ‘homework’ for each module could be the way forward.”

“I believe problem based learning can be used in cognition with the classic lecture style teaching. It should be used to enhance the students learning of a subject, although all people learn in different ways.”

Achievements through problem solving

“I thought it was an interesting project that provided me with a new insight into different analytical techniques and how they can be used to solve a real world problem.”

“This experience has also been advantageous in giving me a true insight into how analysis is carried out in industrial settings. It has shown how it is important to only use techniques that are appropriate to the task in hand and how costly analysis can become. I am now more aware of how problem solving is tackled strategically in a step by step process in order to give the best outcome.”

“I found that I enjoyed researching and locating information. I found it more rewarding to discover evidence that supports theories in my mind, than being fed from a lecturer.”

"I have learnt more using this method than if it were purely lecture delivery. By being assigned tasks to complete including research, I have read around the subject rather than focus on lecture notes."

"It was a good opportunity to experience the sort of processes that food companies would go through to discover the reasons behind any reported problems in the products. It was also a good opportunity to work in a team and to take a further look at a few types of spectroscopy."

Pace of learning:

"I was assigned task sheets to complete each week. This helped me a great deal when it came time to write assessed essays as the information I had learnt at home had been retained."

"In a lecture, which is roughly about an hour and a half, I feel sometimes that my concentration fades, yet with the C/PBL you are free to spend as little or as much time as you wanted on it. It was also good that as a group we met once a week to discuss our findings and how we were getting along with the project."

"I have learnt that there is not always a fast, straightforward solution when solving real-life problems and there may be many steps in finding an answer."

Problems/difficulties/barriers:

"The report itself was much longer than I anticipated. I found this a little excessive because we also had essays and lab reports due in at the same time and I struggled to keep up. As the weeks went on, I found that the tasks got harder and longer and near the end, I struggled to understand a lot of the work and simply could not keep up."

"The only problem I feel that I faced personally, was that I would have liked to have spent more time on the tasks given, however with coursework and exams looming I had to be very self-disciplined with my time."

"I found that occasionally I was wondering away from the field I was meant to be learning about, for example because I have previously learnt about gas chromatography in an analytical methods module, I found myself looking at the more advanced techniques and ignored the basic principles, moving further away from what was needed for the project."

"Self-discipline was probably the hardest aspect of the course."