Final Report

Project title:

"Understanding and improving students' learning experience and engagement with practical science on-line: The case of virtual and remote microscopes"

Keywords:

online learning; teaching; virtual microscopy; pedagogy; students

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Executive Summary

There is a need to better understand what works best for students who study practical science online in order to improve their overall learning experience. In this project, we explored students' and teachers' perceptions about how the Virtual Microscope (VM) is used in online and distance teaching and learning settings. In Study 1, we interviewed 11 and surveyed 139 students from the Open University and the University of Aberdeen who were using the VM in online and blended learning conditions respectively. Students in blended learning conditions were found to be more engaged and satisfied with the use of the VM due to its systematic use in module design, its complementary use with a physical microscope, and the ongoing provision of tutors' support and guidance. Equally good perceived learning gains were reported by both blended and online only students. In a follow-up study, we interviewed 12 teachers from the Open University who had previous experience of using the VM in online and distance learning courses and who had varied roles such as authoring VM activities, authoring courses or were members of the course design team (yet not involved in authoring activities). Findings revealed a variation in how the VM is integrated in different Health and Earth science modules. Also, teachers raised the need for better supporting students when interacting with the VM and proposed a set of ways for improving both the pedagogy and the functionality of the VM software.

Aims and scope of project

The aim of this project was to understand what works best for students who study practical science on-line in order to improve their overall learning experience, in particular, (a) understand how students make use and engage with the VM in online courses at the Open University, and how their experiences compares to students interacting with the VM while studying at a campus-based university, and (b) capture teachers' perceptions about the pedagogy around the VM and their suggestions for improvements.

In Study 1, we answered the following questions:

- What are students' usage patterns of the VM?
- How satisfied are students with how the VM is used in their modules?
- What learning conditions (*online only versus blended learning*) do students report as better supporting their learning and engagement with the VM?

In Study 2, we answered the following questions:

- What are the teachers' perceptions about the integration of the VM in online pedagogy (teaching, learning, assessment)?
- What are the teachers' perceptions about the students' benefits from using the VM in online courses?
- What are their suggestions for improving the design of online courses that make use of the VM?

Activities

The overall project approach aimed to capture the perceptions of both students and teachers in relation to the current teaching practice around the VM in OU modules and identify ways of improving how the VM is integrated in online and distance settings for a better learning experience. The main project activities were:

1. A review of relevant literature about the use of virtual (online) microscopes (e.g., motivation, learning effects) - *see published paper*
2. Design and distribution of online survey to OU's and University of Aberdeen's students
3. Design of interview protocols for students and teachers
4. Ethical approvals for Study 1 and 2.
5. Data collection (interviews, survey, learning analytics) related to students' use and engagement with microscopes from two OU modules and one module from the University of Aberdeen.
6. Data analysis and reporting – *see published paper*
7. Creation of an alternative learning activity about how microscopes could be used in online courses – *see screenshots in Appendix A*.
8. Coordination with module teams to make changes (e.g., integrate the above activity) in 2017J module presentations

In **Study 1,** we completed the following data collection activities:

1. Learning analytics data showing how often students access the VM webpage. These data captured the usage patterns of students.
2. Survey completed by 139 undergraduate students: Year 2 Earth Science (N=37) and Year 3 Biology (N=36) students from the Open University and Year 1 Earth's Materials (N=66) students from a campus-based university where the VM was used in blended learning conditions (face-to-face and online learning).
3. Interviews with 11 students used to trangulate findings from the survey.

In **Study 2**, data were collected from 12 interviews with OU academics who had previous experience of using the VM in online and distance learning courses. Four (n=4) of the participants used the VM in Health Science courses, seven (n=7) in Earth Science courses and one academic (n=1) in both Health and Earth Science courses.

Unanticipated changes

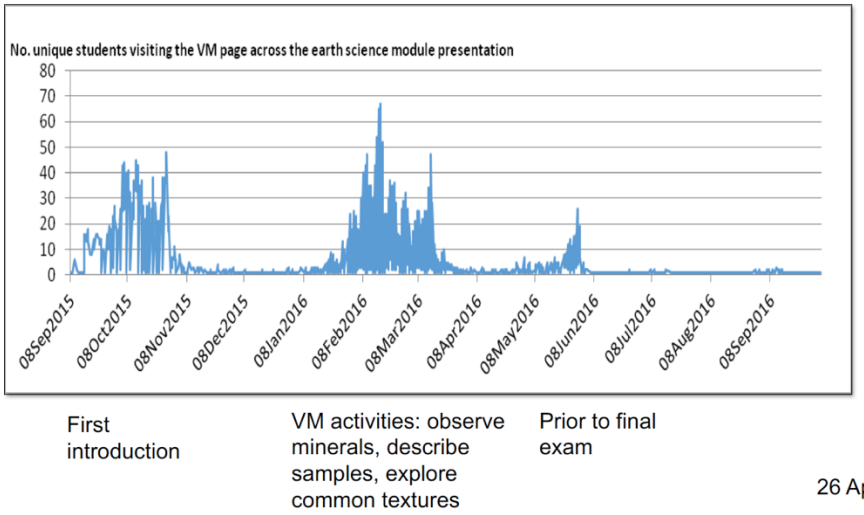
A major challenge faced was to implement changes and improve the design of VM activities in participating modules based on students' feedback from Study 1. OU module teams were nonresponsive in supporting

the implementation and integration of an alternative VM activity that would provide to students support and guidance (in accordance with survey outcomes). This was either due to a lack of resources (time and financial constraints) or a lack of flexibility in modifying OU modules after they go live. In consultation with the eSTEeM Director, the approach and focus of Study 2 were modified to include interviews with academics instead of making actual changes to the current VM practice and re-evaluating student perceptions and participation.

Findings Study 1

Learning analytics findings: As shown in Figure 1, OU students visited the VM webpage at specific points duration a module's presentation (see picks of activity), related to: (a) the introduction to the VM, (b) when activities requested from students to engage with the VM such as to observe minerals and describe samples, and (c) prior to the final examination. A similar picture applies to the Year 3 Biology course.

Figure 1: Unique students per week (Earth Science module)



Survey findings: A series of ANCOVAs were performed to identify whethere there were statistically significant differences between the OU and Aberdeen students, as reported in the survey. Given that the two cohorts of students presented dissimilarities in terms of gender and age variation (79% female OU students & 38% female Aberdeen students; Average OU student age: 40 years; average Aberdeen student age: 21 years old), ANCOVAs controlled for differences in age, gender, module type, previous experience of using a physical microscope and a VM, and problems encountered when using the VM.

(a) OU students made more frequent use of VM features than Aberdeen students and this difference was statistically significant. This is not a surprising insight given that OU students have access only to a virtual and not a physical microscope, and thus the VM is their only means to examine and understand samples.

(b) No statistically significant differences between the two groups of students were found in relation to perceived learning gains from using the VM. Entering covariates one by one in the model, it was identified that age was the covariate explaining differences between groups suggesting that

perceptions of learning from using the VM is a function of age and not of the teaching condition (blended, online only).

(c) There were significant differences in satisfaction with the teaching approach (the way the VM was integrated in teaching) with Aberdeen students being more satisfied than the OU students. Follow-up questions explored the conditions under which the VM could be used; using the VM as part of an investigation (or assessed investigation) was endorsed by approximately half of the students in each cohort (Aberdeen: 57%, OU: 42%). Online tutorials and other tutor-led activities were more favoured by Aberdeen students (65%; 53%) as compared to OU students (30%; 34%).

Survey and Interview findings (combined):

Interview data suggested that frequency and duration of VM use depends on the type of activities and assessment students were required to complete. Although Aberdeen students were found to enjoy more the VM than online students, after controlling for age, gender, and previous experiences of using microscopes, no differences between the two cohorts of students pertained. Age was the covariate explaining differences between groups, suggesting that perceptions of enjoyment from learning with VMs depend on the age of students. These findings align well with existing studies reporting that the VM is endorsed with enjoyment and enthusiasm by students (e.g. Thomas et al., 2014).

In terms of perceived learning gains, all students perceived the VM as mostly enhancing their observation and identification skills and their understanding of what is taught in the course. They reported improvements in learning how to determine the magnification of materials, confidence in using the VM, while they recognised the importance of the VM for accomplishing the course aims. Statistical comparisons between the two cohorts of students revealed that age was explaining observed differences in perceived improvements in observation skills between cohorts suggesting that using the VM in blended (along with a physical microscope) and online learning conditions can equally cater for students' learning needs (e.g. Brown et al., 2016). Interviews revealed a universal preference from both campus and online students to use a physical than a virtual microscope due to for example, engaging with the process of preparing thin sections.

In terms of students' perceptions about the pedagogical integration of the VM, quantitative analysis revealed that Aberdeen students liked the pedagogical integration surrounding the use of the VM in the course more than OU students liked the integration within their online course. Students in blended learning conditions were more satisfied with how the VM was integrated in their course as opposed to online students. Interview data illuminated further this discrepancy; campus-based students used the VM for a variety of learning activities including quizzes, assessment, homework, looking at additional material, and analysing sections on bigger screens, while online students used it as a means to practise observation and identification of sections. For the former group, the VM was complementary to a physical microscope,

while for the latter the basic means of viewing and understanding images. In addition, the role of the teacher was found to be crucial in the learning experience. While campus students explained that the VM was introduced by their tutors though different activities, the online group stressed the need for a tutor to complement online VM activities, tutorials and videos, and provide feedback to their understanding. This finding aligns well with existing studies reporting on the importance of the tutor as discussion facilitator in online learning environments than in blended learning ones (Hung & Chou, 2015).

In terms of which pedagogical conditions better support engagement and learning, findings from this study indicate that blended learning conditions better support students' engagement with the VM, mainly due to the high frequency of using the VM in a course, its complementary use with a physical microscope, and the role of tutors in supporting and guiding students' learning. This is largely due to the VM being fully integrated to the course and not simply an adjunct.

Findings Study 2

A variation in how the VM is integrated in Health and Earth science modules was identified. Teachers reported different ways of introducing the VM to students and designing activities that make use of it. At the moment, there is not a consistent way or an agreed best practice on how to use the VM in online and distance learning. A significant aspect of current practice is how students request and receive support when they interact with the VM; this is either through posting to forums and requesting help from their tutors or peers or in other cases, tutors themselves initiate and provide additional support by for example preparing and posting relevant videos to students' forums.

Teachers' perceptions about the integration of the VM in online pedagogy (teaching, learning, assessment): Teachers stressed the added value of using a VM in online and distance learning; they perceived the VM as a means to provide hands-on, interactive science experiences to students online as opposed to reading materials and lecturing. They saw the VM as being easier to use by manipulating buttons on a website, whereas a physical microscope requires additional training about how the tool functions, for example, how to manipulate magnification and focus or change the field of view.

The use of VM has certain benefits for the teaching practice as well; it allows teachers to better monitor and scaffold their students' interactions with the slides and also integrate the VM in assessment activities. A huge advantage of using the VM for teaching is "being able to see exactly what the student can see" in contrast to a physical microscope, where every student gets a different thin section. With all students getting the same image "you can give the students coordinates, and they go to exactly that spot and you know exactly what they're looking at" and you can also use it "for a far more uniform assessment for all the students".

Teachers' perceptions about the students' benefits from using the VM in online courses: Teachers believed that the VM is easy to use and beneficial to students' learning. They perceived it as reinforcing student's understanding of the benefits from using microscopy to identify slides and the development of students' observation skills, essential in disciplines such as Earth Sciences. Other advantages of using the VM in teaching include "training students to develop different skills which are more useful, online, on-screen skills", the ability of "adding labels to the slides" and also greater time spent on teaching about the slides rather than training students how to use the microscope (as in the case of a physical microscope).

Teachers' suggestions for improving the design of online courses that make use of the VM: Teachers had a range of ideas as to how to improve pedagogy around the VM, indicating that (a) it is important to engage in the design or redesign of modules educators who made use of the VM with students in its current form and (b) certain changes are needed to improve the overall learning experience. In particular, they raised the issue of inadequate support when students interact with samples online, that may not help them identify elements on a slide, explain possible misconceptions, and raise additional questions and answers through discussion with the teacher and peers. These observations were related to a broader perception that supporting students in online distance learning settings is harder than in face-to-face learning, where a teacher can observe what each student is doing and intervene the moment they need help.

Teachers' proposed improvements to VM pedagogy:

1. Student support: Synchronous online hands-on labs facilitated by tutors during which students complete activities using the VM: "What would be great would be to facilitate synchronous lab time for students where there's a tutor present but the students are getting on with whatever activities they want to get on with but were using the same tool, but if they have any questions they can just ping a question to the tutor in a bit like a demonstrator in a practical session in a face-to-face university. Somebody is there to answer their questions for that hour."
2. Process of design: Tutors should be engaged with the process of designing activities with the VM: "We should always try and engage the tutors in a briefing on anything that's dramatically new or different, get them on side, sort out any problems they might have and then they're better equipped to give students the best possible learning experience."
3. Learning objectives: VM Activities should not only focus on counting and measuring, but also on comparisons across slides and the development of metacognitive skills: "I think it's got to be something to do with measuring, counting, looking for associations, so at the moment […] I'm counting and measuring. Now what would be good is some activity where you maybe look at something in association with something else. When you see this do you always see that? Maybe distance from things. Is this always associated with a particular structure? There's got to be something we can do like that."

4. The importance of place-based or contextual learning: Engage students with satellite images from, for example, Google maps: "Working with satellite images of the earth's surface is perhaps another thing to look at. Different scale of module, you're looking at features which are kilometres or hundreds of kilometres across whereas with a microscope you're looking at things a few millimetres across […] you could encourage them to use Google Earth so they go and look at a piece of California and then at certain hotspots you can click on a particular point and have a look at a rock from there and you can then click on the rock and have a thin section. So in a way you can invite the student to create their own geological map with these resources.
5. Functionality: Adding a function that allows sending screenshots to the forum: "if on the forums it were made easier for them to, for example just post an image rather than having to attach it, it's if they could go straight into the text it's something they take from the microscope, then that might encourage them to discuss it more."
6. Functionality: Integrating a microprobe that would make the images interactive: "one of the things that we'd like to develop [for] the virtual microscope is what we call a kind of virtual microprobe where you could literally pick a spot in the thin section on the virtual microscope […] It fires an electron beam at the minerals to analyse their composition."

Project successes

- A major success of this project is the collaboration with the University of Aberdeen that resulted in the implementation of a comparative study examining different teaching and learning conditions and their impact on students' perceptions.
- The project requested and has been successful in securing additional funding from eSTEeM for analysing , in addition to the students' perspectives, the teachers' perspectives.
- Outcomes from the project have been disseminated in a number of venues including national and international conferences – see EARLI2017, Horizons in STEM Higher Education Conference 2017, eSTEeM Annual Conference 2017, as well as at the seminar held in celebration of the 40 years of the Computers and Learning Research Group (CALRG).
- Outcomes from Study 1 have been published in the journal of Interactive Learning Environments and will also be included in an edited book about the 40 years of the CALRG.
- Outcomes have been disseminated at both the University of Aberdeen and the University of Edinburgh (Prof Simon Kelley).
- The project publication has been shared with participating teachers and other module teams.

Impact

- **Student experience**: The project provided valuable insights as to how to improve the pedagogy around the use of VMs in online modules. These insights could inform module teams and the

design or design of modules that make use of the VM. The dissemination of outcomes outside the university can contribute to informing the pedagogy in other HE institutions.

- **Teaching**: We have been less successful in directly influencing the teaching practice at the OU as constraints (financial and others) made impossible the application of insights to practice i.e. improving the design of existing activities that make use of the VM in Health and Earth scienc courses.

List of deliverables

Conference papers and presentations:

- Herodotou, C. (2018). Best practice in teaching with the virtual microscope: a comparative study of blended and online learning. Presentation at the **7th eSTEeM Annual Conference**, Open University, UK.
- Herodotou, Christothea; Aristeidou, Maria; Kelley, Simon and Scanlon, Eileen (2017). Students' engagement with practical science online: Pedagogical implications of the use of virtual microscope in distance learning. In: **EARLI 2017**, 29th August - 2nd Sept 2017.
- Muirhead, David K.; Herodotou, Christothea; Aristeidou, Maria; Hole, M. J.; Kelley, Simon; Scanlon, Eileen and Duffy, M. (2017). A Comparative Study of Blended and Online Learning using the Virtual Microscope for Earth Sciences. In: **Horizons in STEM Higher Education Conference**: Making Connections and Sharing Pedagogy, 39 June - 30 June 2017, Heriot-Watt University, UK.

Journal publications:

- Herodotou, Christothea; Muirhead, Dave K.; Aristeidou, Maria; Hole, Malcolm J.; Kelley, Simon; Scanlon, Eileen and Duffy, Marcus. (2019). Blended and online learning: A comparative study of virtual microscopy in Higher Education. *Interactive Learning Environments*. DOI: https://doi.org/10.1080/10494820.2018.1552874
- Herodotou, Christothea; Aristeidou, Maria; Scanlon, Eileen (in preparation). Teachers as designers: The pedagogical integration of Virtual Microscopes in online courses. *To be submitted*.

Figures

Figure 1: Unique students per week (Earth Science module)

References

Brown, P. J., Fews, D., & Bell, N. J. (2016). Teaching veterinary histopathology: A comparison of microscopy and digital slides. *Journal of Veterinary Medical Education*, 43, 13–20.

Thomas, A., Ng, W., Hill, S., Rizvi, H., Radia, D. (2014). A virtual microscopy learning platform – a high quality, innovative and interactive tool for training haematologists of the future: A UK pilot study. *Blood,* 124(21), 4846.

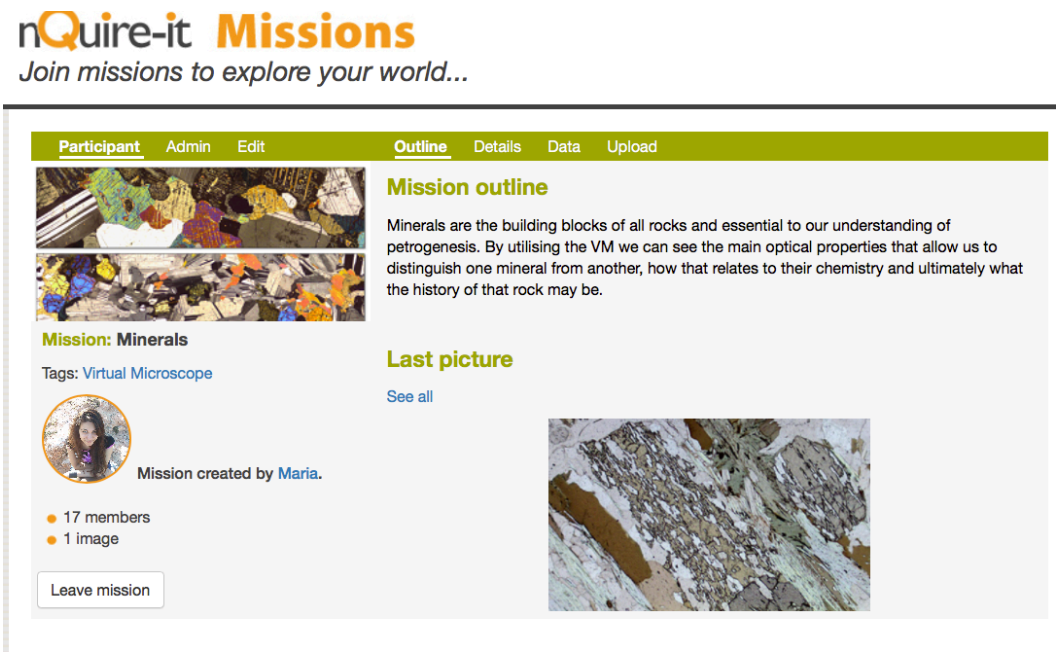
Hung, M., & Chou, C. (2015). Students' perceptions of instructors' roles in blended and online learning environments: A comparative study. *Computers & Education,* 81, 315–325. doi.10.1016/j.compedu.2014.10.022.

Statement of ethical review

An ethical review was obtained according to the Open University's code of practice and procedures before embarking on this project. Reference number HREC/2018/2824/Herodotou.

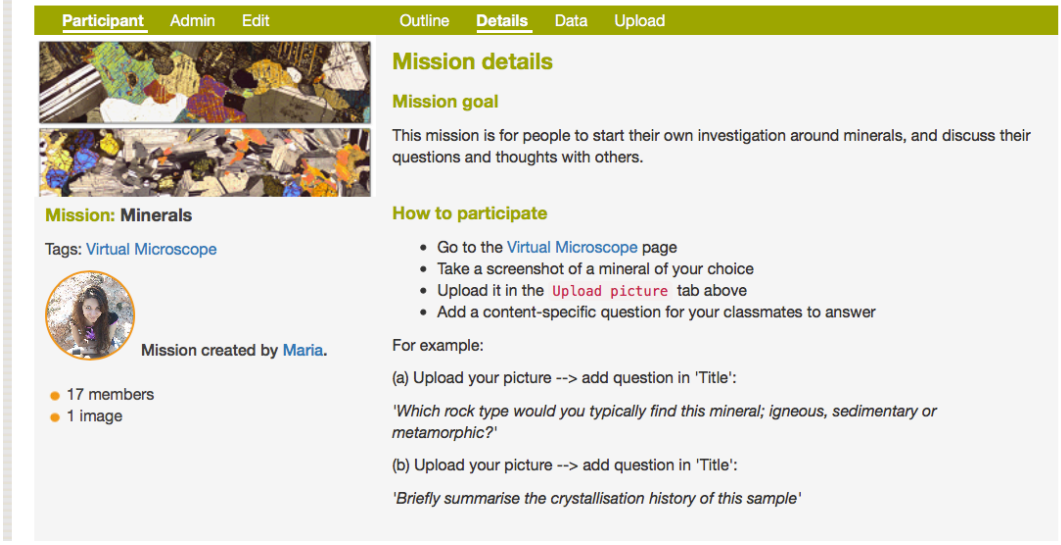
Appendix A

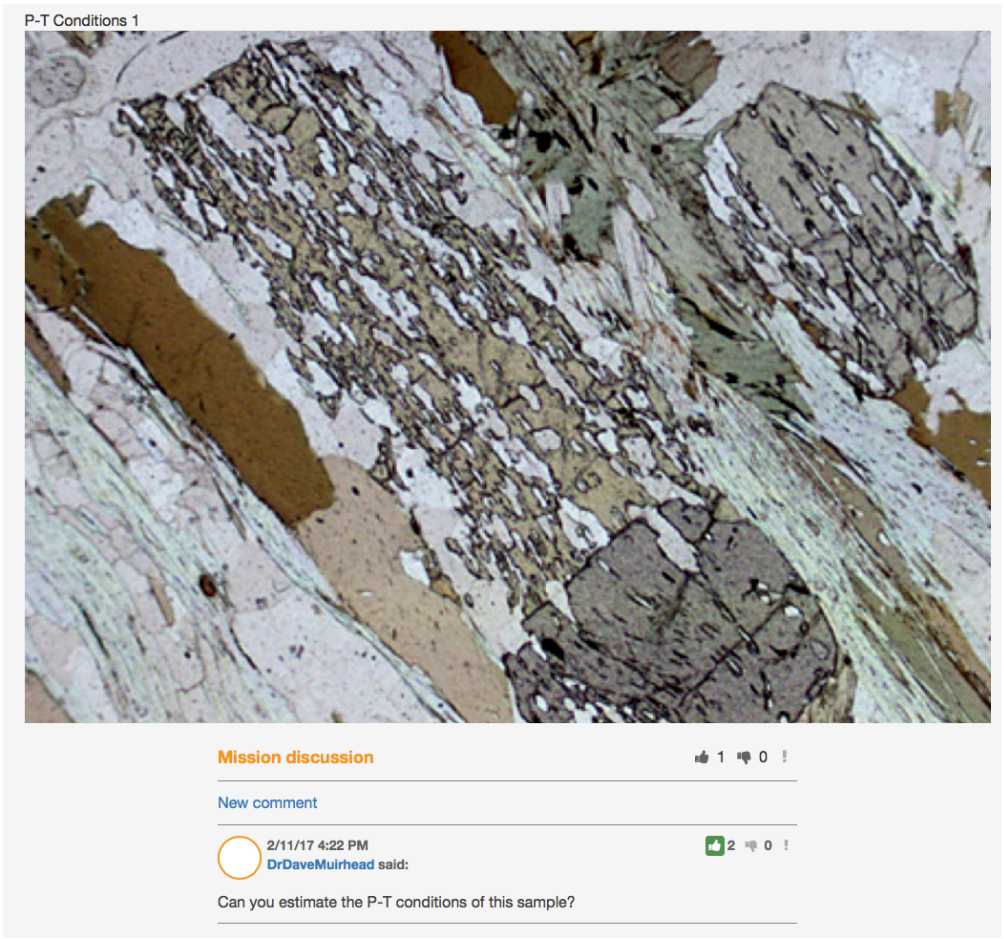
Screenshots from an altenative VM activity. This is hosted on the nQuire-it.org platform (managed by the OU) the purpose of which is to support learning through engaging learners with the process of inquiry. The activity was created in collaboration with the University of Aberdeen and it asked students to take screenshots of minerals from the VM and set questions for others to answer about these images. http://www.nquire-it.org/#/project/4227128



nQuire-it **Missions**

Join missions to explore your world...





Appendix B – Confidential Commentary

Please provide a short commentary providing feedback, for internal use only, about being an eSTEeM project leader. We see no need to restrict the format of this commentary but we have provided some questions that might serve as prompts. The commentaries are intended for use by the management team of eSTEeM.

My collaboration with the Esteem Centre has been excellent. From start, they helped specify the original plan and engage specific modules and their students in the process of data collection. They also encouraged participation to conferences and other science-related events, covering all relevant expenses. They were very response to the difficulties we faced with module teams and they advised on refocusing the aims of the project. We are now looking for submitting a new project proposal for consideration by the Centre and also join this year's Esteem conference. It would be great if the Centre could help further with the dissemination of projects outcomes by, for example, sharing project publicatons with its members or other existing contacts.

Please email your a) written report; b) executive summary; c) deliverables each as separate files (clearly listed in the written report); and d) confidential commentary to esteem@open.ac.uk no later than 2 months post-completion.