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TEACHING UNDERGRADUATE ASTROPHYSICS WITH PIRATE

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RESUMEN

PIRATE es un observatorio de investigación y enseñanza de 0.43m de la Open University en Reino Unido. Desde 2010 ha estado reservado durante varios meses para enseñar astronomía bajo el programa de pregrado de la OU. Dado que los estudiantes en este curso operan PIRATE remotamente, en vez de viajar al observatorio en sí, decidimos investigar si el aprendizaje efectivo era afectado adversamente por la ausencia de una experiencia práctica más tradicional. Discutimos las perspectivas de los estudiantes respecto a las tecnologías utilizadas (por ejemplo: investigaciones remotas y virtuales), el impacto que éstas han tenido sobre el resultado de los cursos y consideramos las implicaciones para enseñanza y divulgación futura

ABSTRACT

PIRATE is a 0.43m semi-autonomous research and teaching observatory owned by The Open University, UK. Since 2010, it has been reserved for several months of each year for teaching astronomy in the OU's undergraduate programme. As students in these courses operate PIRATE remotely rather than travelling to the observatory itself, we chose to investigate whether effective learning was adversely affected by the absence of a more traditional 'hands on' experience. We discuss student perspectives on the technologies employed (i.e., remote and virtual investigations), the impact these had on perceived course outcomes, and consider implications for future teaching and outreach.

Key Words: miscellaneous — methods: statistical — sociology of astronomy — techniques: photometric — telescopes

1. INTRODUCTION

Although many would agree that opportunities for live observation are indispensable in astronomy education at university level (Lockman 2005; Privon et al. 2009), the traditional approach assumes physical access to a suitable facility collocated with the host institution. Funding a campus-based observatory is not necessarily within the budget of every academic institution. Even those that can afford one are often located in urban areas where special measures must be taken to maximise the chances of good observing conditions (Ruch and Johnston 2012).

An additional obstacle encountered by distance learning institutions—The Open University[3] (OU) being one of the world's largest—is the distributed nature of their student populations. Here coursework is delivered not in typical 'brick and mortar' auditoria but via online meeting rooms and tutor group forums. While residential weekends are still offered to give science students an opportunity to experience 'hands on' laboratory work, in astronomy the scarcity, limited capacity, and geographical location of suitable facilities restricts the number of students for whom a physical visit is a realistic possibility.

2. BACKGROUND

To overcome such limitations, in 2008 the OU installed PIRATE[4], a 0.43m semi-autonomous telescope, at the Observatori Astronomic de Mallorca (OAM) in Costitx, Mallorca, Spain. (For a more detailed account of the impetus, implementation, technical specifications and research achievements of PIRATE, see Kolb 2014, this volume.)

In 2010 access to the robotic telescope was opened up to those studying a level-3 OU astronomy course, which effectively meant that undergraduates living anywhere in the world now had the chance to control the instrument live without needing to travel to Spain. Having thus established the feasibility for more advanced students, in 2012 the educational remit of PIRATE was expanded again to encompass those on the Physics and Astronomy strand of the OU's level-2 dedicated practical science course.

Making live operation of a research-grade instrument available to students at this level is rare enough, but the technical challenges of ensuring the system functions smoothly when operated by a team of geographically-distributed participants is not one

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typically faced by organisations with a resident population of undergraduates. To maximise the chances of successful observing with PIRATE, the OU provides students with a realistic virtual telescope on which to practice beforehand, leverages existing synchronous communication tools (e.g., Skype) and assigns each student group a 'night duty astronomer' for initial consultation and emergency troubleshooting. In all other respects, the course of each session is entirely up to the student teams themselves, which evokes both the freedom of action and key time management skills so typical of 'on site' astronomical observation.

3. CURRICULUM

One of the questions considered by this study was whether there were key differences in the perceptions and outcomes of the students in either cohort, despite what was essentially an identical remote observation experience—barring duration, as described below. For this we must consider the role of each 9-month course in the overall curriculum.

The relevant undergraduate qualificaiton offered by the OU is the BSc in Natural Sciences[5], equivalent to three years of full-time study. Courses are designated 'level-1', 'level-2' and 'level-3' in increasing order of difficulty and roughly correspond to the 'year' in which a traditional university student might encounter them.

Thus the aforementioned level-3 course ('Astrophysics') is one students typically complete near the end of their BSc degree pathway. Its enrolment since inception has increased gradually from 156 students in 2010 to 196 in 2014, of which typically a third pursue the project option involving the robotic telescope. These students spend the central 11 weeks of the course working in groups of up to 10 students, with the goal of acquiring a photometric time series of periodic variable stars observed with SuperWASP and coincident with a ROSAT x-ray source.

Over this period, each group has 7 full nights reserved on PIRATE for real-time observation—typically attended by 4 students per session—with the roles of telescope operator, observer's log keeper, and environmental and webcam monitor being exchanged by those present over the night.

By contrast, the level-2 course examined in this study ('Practical Science: Physics & Astronomy') is more general and taken earlier in the qualification pathway by a wider variety of students. Its enrolment jumped from 155 in 2012 to 266 in 2014. Those completing the robotic telescope project are limited to 60 students in each presentation due to time constraints on PIRATE's availability.

Since these students are only allotted half a night of observing time on PIRATE during their first major block of coursework—here lasting only 5 weeks—each group is assigned a correspondingly simpler task: to construct a colour-magnitude diagram for three different types of star clusters.

4. RESEARCH AREA

Our study of these two cohorts' engagement with PIRATE forms part of longer-running research into the effectiveness of delivering practical science instruction via specific distance learning technologies:

- *remote investigations*—which provide students with remote control of geographically-distant real-world scientific instruments (e.g., PIRATE);
- *virtual investigations*—which are software-based reconstructions of experimental or observational facilities (e.g., the virtual telescope that the above students practice on before using PIRATE)

We have targeted three foci as central to the use of such approaches for achieving their intended learning outcomes:

- *authenticity:* whether students perceive the associated learning experiences to be sufficiently realistic, relevant and reliable as compared to a more traditional 'on site' activity;
- *sociability:* whether the instructional design of the remote or virtual investigation promotes collaboration and/or accommodates solitary learners
- *metafunctionality:* whether learning is enhanced or hampered by the incorporation of features that would not be possible on a real-world scientific instrument (e.g., allowing students to alter the natural flow of time during an experimental activity)

5. RESEARCH METHODS

To determine the impact of these aspects on effective student learning, multi-stage surveys were designed for each cohort, eliciting student feedback at three points during each course:

- initial pre-engagement attitudes and course expectations before the project began;
- immediate post-completion perceptions and self-reported outcomes when the project concluded;
- end-of-course reflections on how well these distance technologies fit into the greater scheme of the course itself

Trends and potential issues identified in the responses to earlier questionnaire stages were then followed up in a series of focus group discussions

[5] http://www.open.ac.uk/study/undergraduate/qualification/q64.htm

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with a self-selecting (i.e., volunteer) sample of students from either module, as well as semi-structured interviews conducted with their course tutors for comparison. Moreover, statistical correlations were sought between student demographic and questionnaire data and their eventual assessment outcomes, as outlined in our poster in this volume (q.v.).

The above elements were chosen in order to permit a mixed-methods approach to be implemented. Assessment outcomes and Likert-scale responses were analyzed using IBM SPSS Statistics 22, whilst thematic and discourse analysis was undertaken of the interviews and focus groups. The rationale was that the later qualitative material would clarify the earlier quantitative data, but in reality the focus groups highlighted additional student concerns not immediately evident from the questionnaire responses alone (see § 6.2).

6. STUDENT RESPONSES

6.1. *Pre-engagement opinions*

Pre-engagement opinions held by students in both modules included:

- the expectation that the project would increase their *subject knowledge* but not actually improve their *teamwork skills*;
- a belief that *self-study* is the most useful method of learning science whilst *tutorials* and *discussion forums* were the least useful—other options included lectures, practical work, and data analysis

Key contrasts between the two cohorts also emerged, however. Much more than their level-2 counterparts, *the level-3 students*:

- possessed greater prior work experience with *experimental data collection*
- expected to improve their *experimental techniques*;
- expressed *less confidence* in their existing practical science abilities;
- felt remote work *would be equivalent* to making observations on-site

Considering that the level-3 students on the whole performed better on every assessment measure, one interpretation of the above difference is the Dunning-Kruger effect (Kruger and Dunning 1999). This is an observed cognitive bias often confirmed in pedagogical studies—e.g., Galloway et al. (2013)—where more competent individuals consistently underestimate their abilities, whilst less competent individuals overestimate their own.

6.2. *Post-project perceptions*

The above contrast in anticipated equivalency between remote and on-site practical work was further borne out by the post-project questionnaire responses, where *the level-3 students* were far more likely than level-2 ones to *agree* that:

- remote control of PIRATE *felt like being right there at an observatory*;
- the experience of making live observations was *more enjoyable than frustrating*;
- they had been granted *an adequate amount of observing time* on the robotic telescope

These last two perceptions were also raised repeatedly by level-2 participants during the focus group dialogues and seem interlinked. Many students in this cohort found the single night on PIRATE to be overly restrictive, as it meant that there was no 'elbow room' in which to recover if observations went slightly off-plan at any point.

Although in theory there was ample time for each student team to collect calibration and science frames for their three selected star clusters, in practice this assumes a level of comfort with the operation of the instrument that some level-2 students simply did not possess during that first (and, for them, only) session. This suggests that they did not take full advantage of the prior training afforded them on the virtual telescope. Instead, it would appear that they used it merely to obtain a superficial understanding of the controls needed for the live PIRATE run but stopped short of actually practicing the various procedures to the point of familiarity.

Moreover, when this led to teams not being able to image all three star clusters, further frustration was expressed at having to use archival data for the remainder of their analysis. While it can certainly be argued that this is a case of the level-2 students coming to the project with unrealistic expectations compared to their level-3 colleagues, it is a factor that should not be overlooked when planning such activities if student satisfaction and continued engagement are among the desired outcomes.

Notwithstanding the foregoing concerns, both student cohorts shared the opinion that:

- synchronous communication (e.g., via Skype) *to coordinate team activities on the live observing night* had been successful and straightforward;
- the virtual telescope had offered *sufficient training* for operation of PIRATE;
- the virtual telescope would be considerably improved if it could *simulate non-ideal observing scenarios*—e.g., by triggering weather-related system errors or emulating autofocusing issues—so students could learn in advance how to respond appropriately in such circumstances

7. INTERPRETATION

These results are encouraging in that they suggest the fundamental instructional design is sound. Undergraduates do feel that joint remote telescope operation by geographically separated observers is a viable approach to learning observational astronomy, the majority reporting 'major' or 'profound' improvement in their understanding of the related data reduction methods typical of such work.

While it is true that the level-3 students on the whole came away with a considerably *more positive* view of the whole experience—and likewise higher assessment outcomes—this may be partially attributable to longer contact time with PIRATE. If this is indeed a key factor, then the level-2 cohort's performance could conceivably be raised simply by increasing their scope time, without any further alteration to the project activity.

That said, student comments suggest that greater educational gains may be realised by implementing specific meta-features within the virtual telescope, which in its current form may be giving students—particularly those who have never before operated a real telescope—an overly idealised impression of the experience. The two

Specifically, in addition to students' aforementioned desire to practice responses to non-ideal observing conditions (per the last bullet point of § 6.2), another concern raised in the focus groups was the disconnect between how long operations took on the actual instrument compared with what the virtual telescope had led them to expect. The software in question simulates certain tasks—e.g., dome control, instrument slewing, camera autofocusing, image frame acquisition—at an accelerated rate (up to 10 times real-time speed).

The expectation had been that this would enable students to achieve more during their practice sessions on the virtual telescope. However, despite this 'time compression' feature being clearly explained in the associated teaching materials, it had the unforeseen consequence of wrong-footing less-experienced students and causing additional stress (and distress) during the live observing nights. The student response to this rationale was that ideally they themselves should be able to specify the level of 'realism' in the timing of scope operations, allowing them to learn the basic controls in the accelerated mode and then have some practice with 'real-time mode' before their booked slot on PIRATE itself.

8. CONCLUSION

Having established the value of PIRATE as an effective teaching resource for live astronomical observation, astronomy educators in the OU seek to maximise the instructional benefit of the robotic telescope by tailoring its use wherever possible to student needs. Specific examples identified in this study include the importance of promoting an appreciation of scientific collaboration among students in both cohorts and of ensuring that level-2 students in particular find the experience of remote observation sufficiently authentic.

In order to achieve this latter aim of authenticity, the evidence suggests that less-advanced students first need to be convinced of the relevance of using a virtual telescope for preparation. Without this step, it appears they may not fully engage with this technology and as a consequence perceive their interaction with PIRATE itself to be insufficient.

Evidently, enacting software modifications such as those proposed in § 7 is more involved than simply allocating additional observing time, but as a shared scientific resource PIRATE must strike a balance between curricular and research goals. Thus a software-based solution may not only be more cost-effective in the long run—as it preserves research time on the actual instrument—but it also opens up new possibilities for educational outreach. (For instance, by providing greater capacity for scenario-based astronomy learning in primary and secondary schools.) As an example of this latter direction, the virtual telescope used in both of the above courses has now been made publicly accessible as part of the OU's OpenScience Laboratory[6] initiative.

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