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Evaluation of an Online Instructional Database Accessed by QR Codes To Support Biochemistry Practical Laboratory Classes

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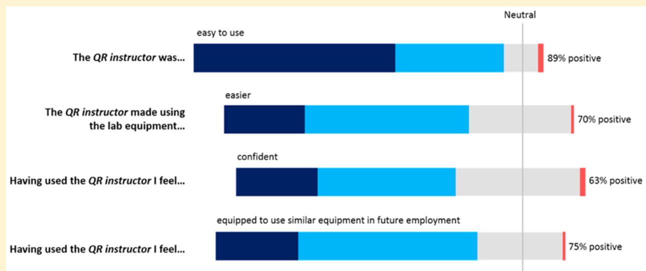
S *Supporting Information*

ABSTRACT: An online instructional database containing information on commonly used pieces of laboratory equipment was created. In order to make the database highly accessible and to promote its use, QR codes were utilized. The instructional materials were available anytime and accessed using QR codes located on the equipment itself and within undergraduate student practical handouts. The database and access mechanism was evaluated during multiple undergraduate practical sessions, and the students were able to provide feedback through completion of a questionnaire. The majority of the participating students reported that the QR Instructor was easy or very easy to use (89%) and made using the laboratory equipment easier or much easier (70%). Just under two-thirds (63%) of the students felt that having used the QR Instructor they were more confident in using the equipment than before, and three-quarters (75%) of students stated that they felt better or much better equipped to use similar equipment in their future employment. Overall, 90% of those students who responded to the questionnaire said that they would recommend the use of the online instructional database. The proposed system therefore has been shown to enable easy access for students to online instructional information as well as enhancing the learning experience with increased student confidence.



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Many students regularly use mobile phones and/or tablets to gain information both within and outside academia. A recent survey conducted by Harris Poll for the Pearson Student Mobile Device Survey 2014 showed that 84% of college students own a smartphone, with 56% using them at least twice a week for school work.[1]

Educators have started to embrace the use of such technology to enhance students' learning through mobile devices,[2] particularly in the field of mobile assisted language learning[3] and more recently in the scientific and engineering disciplines. Williams and Pence[4] stated that there are three main uses for smart phones in education: web browsing to access educational materials; specialist applications; and "smart objects". Smart objects are created by using a physical reference, such as a 2D barcode or quick response (QR) code, to connect a mobile device to information. The process creates a hyperlink for the physical object which can be scanned to allow direct access to digital content: a type of markered augmented reality (AR). Through AR, a composite image is created by using technology to superimpose a computer-generated image onto the user's view of the real world. QR codes can be easily generated using many online, freely available QR code generators and linked to educational materials.

At the University of Huddersfield, for example, the library has used QR codes to provide links to electronic resources, instructional information, and contact details.[5] For example, QR codes were placed next to the physical copy of a book in the library to provide instant access to the electronic book (e-book) version to increase student awareness of the e-book facilities available. Furthermore, QR codes for instructional videos were placed both on equipment, such as print credit machines, and in physical handouts to allow students to access the information at a variety of locations. QR codes have also been used to allow students to take part in formative class evaluations and provide rapid feedback to teaching staff on aspects covered during the session.[6]

More specifically, QR codes have been used in the field of chemistry education from primary school to the undergraduate level. Bonifácio[7] has used QR codes to make information on Nobel laureate prize winners and the periodic table of the elements more accessible to students of all ages. The latter involved the use of videos enhanced with audio description to make the subject matter more accessible to blind and visually impaired students. Students have also been given the opportunity to create their own photo blogs on how to use certain pieces of laboratory equipment, accessed by QR codes, that could be used by their colleagues.[8] QR codes have also

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been used outside of the laboratory; for example, at the Cambridge University Botanical Gardens, a chemical train through the plant holdings has been devised with 22 stopping points where QR codes can be scanned. The students are then directed to information on the chemical components of the plants, including 3D structures, and their applications.[9]

The work presented here demonstrates the use of QR codes to provide instantaneous access to an online database which provides a range of demonstrations for the use of specialist scientific equipment. In practical laboratory classes students can feel uncomfortable with highly technical aspects due to inexperience, extended time since previously used, or simply a lack of confidence.[10] This can lead to poor results in laboratory assessments, misuse or damage to equipment, and further decrease in confidence. Development of the necessary laboratory skills is not only beneficial as part of the undergraduate courses but vital for professional skill development for those students who plan to pursue a career in the practical sciences or engineering professions. The online instructional database was designed to complement information and guidance provided by academic and technical staff in order to promote self-regulated learning. Self-regulated learning "involves more than detailed knowledge of a skill, it involves the self-awareness, self-motivation, and behavioural skill to implement that knowledge appropriately."[11]

The main research aims of this work were (i) to evaluate if the use of an online instructional database could alter the way the students see using laboratory equipment (e.g., level of difficulty encountered, confidence using equipment) and (ii) to determine how user-friendly the developed system was.

■ METHODOLOGY

Development of Instructional Database

Instructional Materials. Commonly used pieces of multidisciplinary laboratory equipment were selected for inclusion in the study, including balances, centrifuges, gel documentation systems, hotblocks, micropipettes, ovens, vortexes, and water baths. Videos were produced for each piece of equipment detailing both general and specific health and safety precautions, as well as detailed step-by-step instructions for correct usage. The videos were all produced within the laboratory where the students would be using the equipment, and the techniques were performed by technical staff who work within those laboratories to create a familiar environment. All materials contained visual information alongside audio commentary and subtitles in order to promote inclusive practice and also enable note-taking. The videos range in length from approximately 1 to 2 min, depending on the complexity of the particular piece of equipment.

QR Codes. All digital media generated was uploaded onto a secure server and hosted through MMUtube (an online video resource for staff and students at Manchester Metropolitan University). In order to facilitate easy, anytime access to the instructional materials, QR codes were produced using a QR code generator (for example, that available at http://www.qrstuff.com). These codes were placed on or near the equipment, as well as in student handbooks provided during each laboratory session. Electronic copies of the handbooks were also available through the Moodle virtual learning environment (VLE), enabling access both prior to the session and at any time afterward, providing the students with 24/7 access to the materials. The QR codes can be scanned at any time by a mobile or tablet device with any generic, free to download QR scanner. This addresses concerns raised in a survey conducted at the University of Bath where students were anxious that use of QR codes could lead to "just in time delivery of information" rather than provision of educational materials in advance of taught sessions.[12] The use of QR codes also offers advantages for academics to adopt the use of the instructional videos within pre-existing practical classes and electronic materials as the QR codes can be quickly printed and stuck onto laboratory equipment and inserted within electronic materials.

Questionnaire

In order to evaluate the instructional database, all students who took part in undergraduate practical biochemistry laboratory classes, within one particular laboratory space, where the instructional database was tested were invited to complete a questionnaire. Students were enrolled in the following courses: BSc Biology, BSc Biomedical Science, BSc Healthcare Science, BSc Microbiology and Molecular Biology, Combined Honors Biology, or Combined Honors Forensic Science (further information on each of the courses is available at http://www.sci-eng.mmu.ac.uk/).

The questionnaire was split into two parts (see the Supporting Information): the first collected demographic data, and the second contained a variety of question types. To enable analysis on a qualitative scale, free-text, open ended questions to gain opinions from the different users were used. These were complemented by using 5-point Likert-scaled questions to allow statistical analysis to be carried out on the qualitative data obtained.[13] All data collection was performed in compliance with institutional guidelines, and ethical approval was obtained from the Manchester Metropolitan University Ethics Committee. Informed consent was obtained from all individuals who participated. Statistical analysis was carried out on the data obtained using Mann–Whitney *U* and Wilcoxon tests in SPSS.

■ RESULTS AND DISCUSSION

Demographics

The instructional database was evaluated during five different undergraduate classes across a range of disciplines. All students who attended the classes were invited to complete the questionnaire. A total of 181 questionnaires were received (81% response rate), of which 6 were not included in the evaluation as they were incomplete. Information on gender, age, degree program studied, and prior familiarity with QR codes was collected (Table 1).

Use of Instructional Database

The instructional database was used by 57% of those students who attended the practical laboratory sessions where the QR Instructor was being tested. For those students who did not use the QR Instructor, the most common reason cited was that they were already familiar with the use of the equipment (19%). Other reasons given were not wanting to download a QR scanner app onto a personal phone (8%), lack of awareness of the evaluation taking place (5%), poor Internet connection in the laboratory (2%), not enough time (2%), or did not have a phone with them (2%).

One student said, "I am not a fan of using online tutorials/videos for help when I can ask someone instead. I feel you can learn a lot more off a person than a computer." It is worth

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Table 1. Demographic Information Collected from Participants

Category	No. of Participants	% (N = 175)
Gender		
Male	69	39.4
Female	106	60.6
Age		
18−21	103	58.9
22−25	63	36.0
26−30	6	3.4
31−40	2	1.1
41+	1	0.6
Degree		
BSc Biology	11	6.3
BSc Biomedical Science	121	69.1
BSc Healthcare Science	7	4.0
BSc Microbiology and Molecular Biology	7	4.0
Comb Hons Biology	1	0.6
Comb Hons Forensic Science	28	16.0
Familiar with QR codes?		
Yes	141	80.6
No	34	19.4

clarifying at this stage, that multiple members of academic and technical staff were present throughout the practical sessions to offer support and guidance and that the QR Instructor was not used as the primary means of learning but to enhance the student experience. While some students feel more comfortable asking a member of staff for advice, as seen in the above quotation, there are others, who, for reasons such as anxiety, may not. Therefore, by offering a range of learning methods within the laboratory sessions the intention is to support all students to engage with at least one form that is effective for them personally.

For those students who did engage, there was a spread in the pieces of equipment that were used (Figure 1). More use of the online database was observed for those pieces of equipment that had not been previously used by the students (i.e., hotblock) or those which were required multiple times throughout the practical sessions (e.g., centrifuge, p200 and p10 micropipettes).

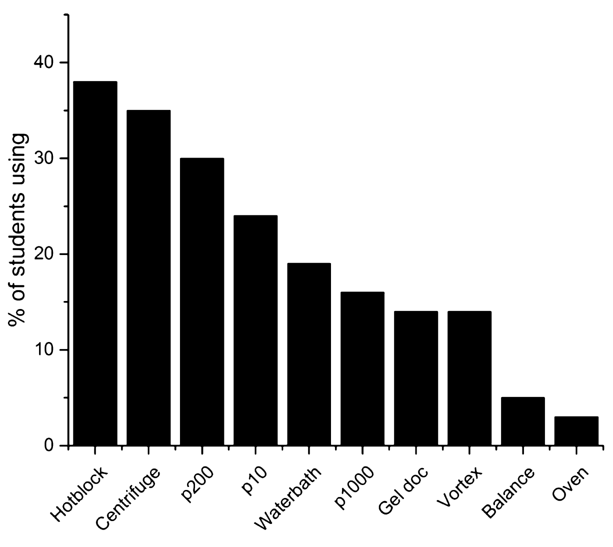

Figure 1. Percentage of students using the QR Instructor for different pieces of laboratory equipment.

Evaluation of Instructional Database

Students were asked to rate certain aspects of the QR Instructor on a Likert scale; the overall results can be seen in Figure 2. The majority of the students (89%) said the QR Instructor was very easy or easy to use. This points to the use of QR codes as an effective way to facilitate student access to instructional information in an easily accessible format.

Overall, 70% of students said that the QR Instructor made using the laboratory equipment easier or much easier, thereby demonstrating that there is a perceived benefit by the students from using the online instructional database. One student said, "It's really good and makes lab work easier." Just under two-thirds of the students (63%) felt that having used the QR Instructor they were more confident in using the equipment than before. Additionally, three-quarters of students stated that they felt better or much better equipped to use similar equipment in future employment. This increase in student confidence in demonstrable skills offers advantages for the students in terms of future employment opportunities.[14]

Statistical analysis was used to look for any trends between the demographics of the students and the questionnaire results. There was no significant effect of gender, age, or prior knowledge of QR codes, on any of the quantifiable questionnaire outputs (Mann−Whitney U test and Wilcoxon test, $p > 0.05$). The lack of any correlation on the prior use of QR codes is advantageous as it shows that those who do not have any prior experience are as likely to be able to use and appreciate the system as those who are already familiar with them. The percentage of students who were already familiar with QR codes was considerably higher than in a 2008 report by Ramsden (2008), where only 12.5% of students knew about QR codes. This is likely due to a more widespread use in QR codes over the past few years. Those students who were taking a biology based subject (BSc Biology, BSc Microbiology and Molecular Biology, Combined Honors Biology, and Combined Honors Forensic Science) reported that using the QR Instructor made using the laboratory equipment significantly easier for them compared to those students taking a healthcare science based subject (BSc Biomedical Science or BSc Healthcare Science) ($Z(130) = -2.334$, $p = 0.020$). For complete statistical tables, see the Supporting Information.

Overall, the QR Instructor received positive feedback and becomes one more tool in the students' toolkit that helps in creating a more inclusive learning curriculum. More students than before are now aware of QR codes, 81% in this study compared to 21% in a previous study,[8] which makes implementation of such information delivery systems easier within the undergraduate laboratory. The QR Instructor and the evaluation of the system support the theory of self-regulated learning. Within the theoretical model, Zimmerman states that there are three times when self-regulation aids the learning process and all three are demonstrated here.[11] First, before the task is tackled, students can develop their own plan to approach the task; e.g., do they feel they need additional support and guidance on using the equipment? If so, they can make use of the instructional materials prior to the session by using the QR codes within the practical handouts provides on the VLE. Second, while performing the experiment, students can choose to access the instructional materials during the session using the QR codes located on the laboratory equipment. Third, self-

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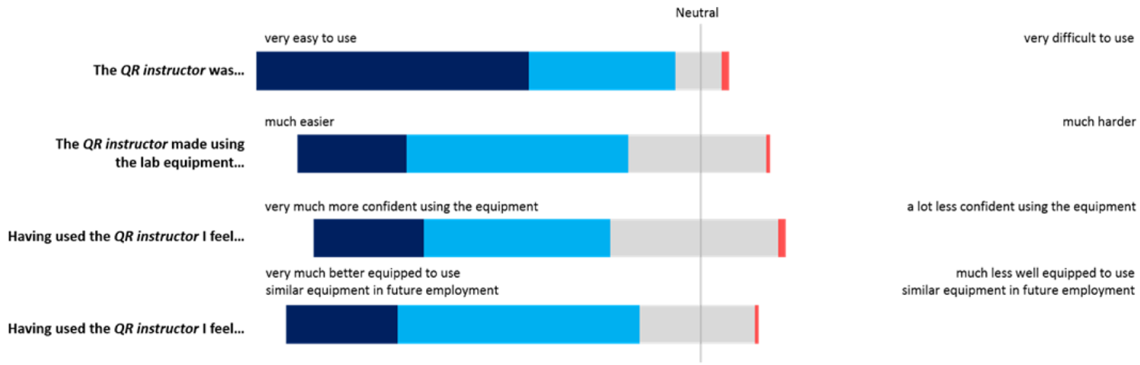

Figure 2. Students' responses to the four statements on the left-hand side, which were graded on a Likert scale from 1 to 5 (1 = dark blue, 2 = light blue, 3 = gray, 4 = light red, 5 = dark red) with the 1 and 5 scale options shown for clarity. Each bar shows the relative percentage of students who selected that scale point and the overall opinion relative to neutral.

reflection: the students can access the instructional materials at a later date after completion of the practical class if they feel the need to do so. Completing the questionnaire also allowed the students to reflect on whether or not they felt more confident with the equipment and in a better position to use similar equipment in the future.

■ CONCLUSION

In total, 90% of undergraduate students who responded said that they would recommend the use of the QR Instructor. The students were also asked what improvements they would make to the existing system. The most common suggestion received was to include additional, more complex equipment as part of the online instructional database (14% of overall respondents). This most frequently included suggestions for videos for spectrophotometers, light microscopes, gas chromatography, and high performance liquid chromatography instruments. Such instruments will require more detailed instructions due to their more complex nature and therefore represent the next logical step in the development of the QR Instructor. This would also assist in broadening the use of the QR Instructor to cover a wider range of disciplines and evaluating the system using a wider student cohort. Other suggestions were of a more technical nature and included improvements to Internet connectivity and sound quality, as well as the possibility of turning the database into an app. Future work will also look at using alternative delivery methods to try to increase accessibility through the use of augmented reality software (Aurasma) which uses more visual cues and can link more types of media together.

Further evaluation of the proposed system will be undertaken, paying particular attention to course performance of those students who have participated and any links to improved employability statistics in future years once students graduate.

Having 24/7 access to the QR Instructor would also see the system well placed to assist those students on distance learning courses, such as the FdSc Chemical Science program offered at Manchester Metropolitan University, where part-time students could engage with the online videos prior to their week long residential visit where laboratory work is undertaken. Equivalency Theory, as explained by Simonson et al., states that "Local and distant learners have fundamentally different environments in which to learn. It is the responsibility of the distance educator to design learning events that provide experience of equal value for learners."[15] By providing online resources which can be accessed at any time, learners can access the information in a timely fashion that suits their individual needs.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.6b00184.

Student questionnaire (PDF, DOCX)
Complete statistical tables (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

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