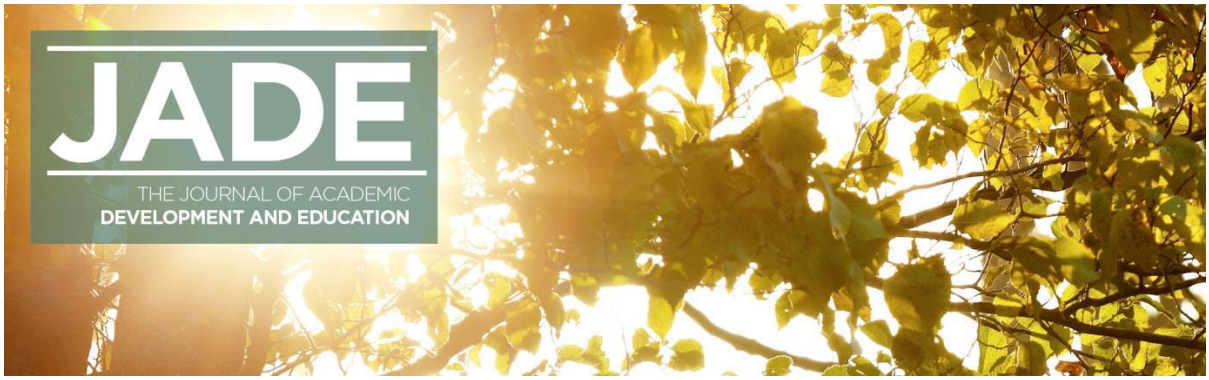

Issue 7

January 2017

ISSN: 2051-3593

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Clickers in the Classroom: Study into the use of interactive quizzes in a practical environment

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Introduction

This study was conducted as part of my teaching and learning with technology (TALWT) project within the School of Medicine at Keele University. In the lead up to this project I had taken over the organisation and running of functional microanatomy practical sessions for undergraduate medical students and as such this became my focus for the project. Traditionally, functional microanatomy, or histology, is taught in a self-directed manner where students have hands-on access to microscopes and slides but very little interaction with an expert and few opportunities for feedback (Sherman and Jue 2009). With the growing emphasis upon the need for higher education institutes to provide timely and constructive feedback to students (Draper and Brown 2004, Blasco-Arcas *et al.* 2013) I decided that my innovative use of technology needed to have feedback at its core. Formative assessment is a tried and tested means of providing feedback on learning to both the student and the teacher (Smith and Cogdell 2006, Alexander *et al.* 2009, Kay and LeSage 2009). Interactive voting systems (clickers) provide an easy, fast, and accessible means of assessing learning, and provide personalised, and anonymous, feedback to students. In addition, if used correctly, clickers provide a flexible learning environment that can be adapted to meet the needs of the learners. This technology, however, has had little use within the practical setting. As such, this project aimed to examine whether formative quizzes using clickers in histology practical sessions promotes engagement with the content, and improves feedback for students. A formative assessment using clickers was conducted at the end of a single histology session for 1st year undergraduate medical students. Answers submitted by the students were anonymous, and a short period of teaching was provided where necessary. The session was repeated three times, each for approximately 40 students. Following the sessions, students were provided with an electronic questionnaire asking for their anonymous feedback on the session. This data is represented here, alongside my own personal reflections on the use of this technology in practical sessions. In short, the project highlighted three major themes. One, the session, and the students, should be appropriately supported - the introduction of a form of assessment does not replace the tutor-student interactions necessary for the construction of knowledge. Two, the assessment must be aligned with the content covered in the session, and the summative assessments to follow. Three, the tutor must be prepared to be flexible in their approach to teaching – responses to a question may alter the course of the session and this is something to be embraced not avoided.

Feedback in Higher Education: Mind the Gap

Many different theories exist around pedagogy and learning styles; most, however, generally accept that it is a social process with feedback as a cornerstone to the successful creation of knowledge and the development of understanding (Steffe 1995, Prince 2004, Draper and Brown 2004, Jisc 2005). It is therefore a major concern that Higher Education (HE) institutes are currently failing to provide appropriate feedback to their learners. The ability of HE institutes to provide feedback has improved over recent years; however the latest National Student Survey (NSS) results show that this is still an area for improvement, with only 68% of students responding that feedback on their work has helped them to clarify areas of misunderstanding (NSS results 2015 and 2016). The undergraduate medical course at Keele fits this trend, with only 83% of students responding that their feedback was prompt (NSS results 2015).

This academic year I became the co-lead for the functional microanatomy practicals (FM, traditionally histology) for year 1 and year 2 medical students. As such, I was keen to determine whether feedback was also an issue within this specific aspect of the course. Internal surveys, completed annually by year 1 and year 2 students, identified participant interaction as the key area for improvement (Figure 1). As feedback is essential to promote student engagement and thus interaction (Epstein *et al*. 2002, Hepplestone *et al.* 2011, Blasco-Arcas *et al.* 2013), it was apparent that the general trend seen throughout the medical curriculum was also an issue within these practical sessions. This had therefore identified the 'gap in the market'; the issue that needed solving.

Whilst considering this specific area of the curriculum, the wider context must also be taken into consideration. Such factors include national strategies, internal strategies (within the medical school), sustainability, and the global shift in pedagogy in HE. With regards to national strategies, there is a call for HE institutions to promote accessible learning and encourage wider participation (Clarke 2003, Simpson 2004). In terms of sustainability, this must include both physical resources, and the time of the instructor. The shift in pedagogy is towards one of social constructivism where learners are fully invested in their own education (Steffe 1995, Prince 2004, Jisc 2005). These factors were considered at all stages of the project.

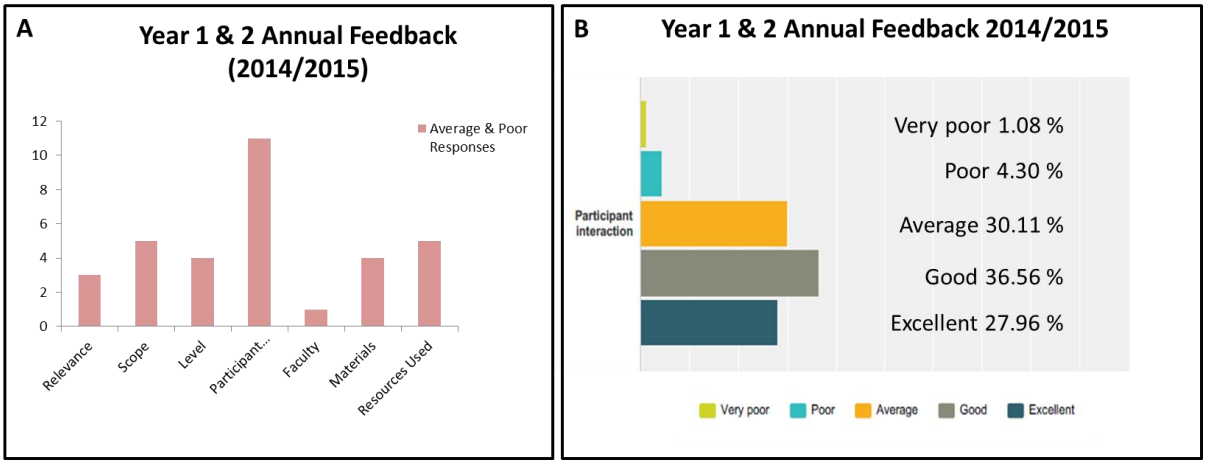

Figure 1: Internal survey data 2014/2015. Students were asked to rate the histology practical sessions on their content, delivery and resources, on a scale from excellent to very poor. The number of average and poor responses is shown in (A). No very poor responses were recorded. The practical sessions received the largest number of average and poor responses for participant interaction (11 average, 0 poor) when compared to the other criteria. B). Approximately 35% of year 1 and year 2 students rated participant interaction as average, poor, or very poor, during histology practical sessions.

Meaningful learning – the ultimate goal

Throughout this project, my aim was to promote meaningful learning in practical sessions. I wanted students to be able to construct knowledge on the foundations of their prior experiences, and to then *apply* this knowledge to novel situations; i.e. to reach a minimum of level three of Bloom's taxonomy of educational objectives (Bloom 1956). Students tend to store their knowledge in isolation, preferring a system of rote memorisation to actually *understanding* the concept (Skinner 2009). This is particularly true in the study of histology where students may have very little existing knowledge to develop upon, and there is a large amount of content. Students often focus on short-term goals (exams), and therefore fail to link any newly acquired knowledge to pre-existing knowledge, and apply it to problem solving scenarios (Alexander *et al.* 2009). Therefore, students must be provided with the toolkit to apply their knowledge systematically to produce mental models, appropriately linked to other models, to allow the accession of information from multiple starting points (Michael 2001); the 'associative perspective' of pedagogy (Jisc 2005).

What is meaningful learning?

> *Rote learning is memorizing all the entries on a page from the Orlando phonebook. I am sure that I have some students who could do this if they thought it would help their grade in physiology. However, if you know nothing about the city of Orlando, a question like "how far from Mr. X does Miss Y live?" is impossible to answer. So your having memorized the 100 names, addresses, and phone number has left you with completely inert knowledge which you can do essentially nothing (except, of course, to recite the list from memory or call a bunch of strangers if you are so inclined).* Exert from Joel Michael's reflective article "In pursuit of meaningful learning" (2001). Michael is a teacher of physiology at Rush Medical College , Chicago.

With this in mind, and for meaningful learning to occur, three factors (and their interactions) must be at the forefront in the design, planning and implementation of any innovation: the learner, the learning environment, and the learning goals (Jisc 2005). These factors in the context of histology can be seen in Figure 2.

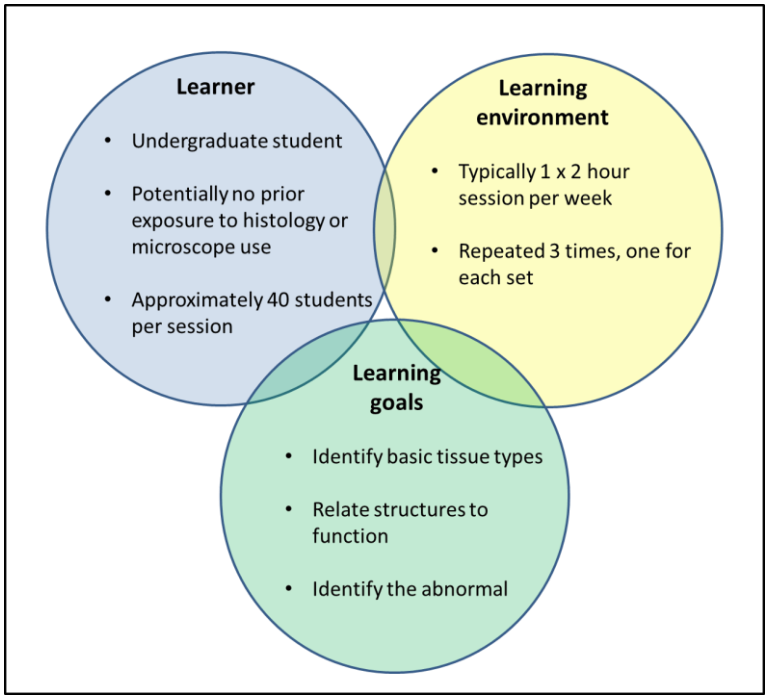

Figure 2: Model demonstrating the three key factors to consider when introducing innovative practice. The model has been applied to the context of a histology session for undergraduate medical students. The time constraints, existing knowledge of the student, and large student numbers are major factors when working to achieve the learning goals. This model was self-generated, with inspiration from the Jisc 'Innovative Practice with E-learning Guide' (2005).

Context

Current practices in histology teaching

Traditionally, histology teaching has adopted an approach of self-directed learning, to the extent where in some instances students are left alone with a microscope and a textbook (Sherman and Jue 2009). More recently, the 10 pedagogical methods for teaching histology have been described by Sherman and Jue as:

1. Self-guided learning
2. Learning with pre-set microscopes
3. Learning with image projection
4. Learning with digitized imaging
5. Cooperative learning
6. Problem-based learning
7. Motor-based learning
8. Instructor-guided learning
9. Organ-based learning
10. Organ system-based learning

At Keele, the approach typically involves a combination of methods 1, 3, 5, 7, 9 and 10, in order to provide different types of learners with equal opportunities to access the learning experience. Despite the range of approaches currently adopted by HE institutions, drawing (motor-based learning) is a consistent theme across most, if not all, institutions (Cotter 2001, Jacyna 2001, Cogdell *et al.* 2012). Indeed, evidence suggests that students who draw during histology practicals achieve significantly higher scores than those who do not ($p<0.05$)(Cogdell *et al.* 2012). As such, this is one aspect of the histology practical that must persist.

National and internal surveys identified student feedback and interaction as an area for development (NSS data and Figure 1). The literature detailed very little use of technology to develop these aspects of the practical classes outside of the use of virtual microscopes or digitised images (Heidger *et al.* 2002, Bloodgood and Ogilvie 2006, Sherman and Jue 2009). As such, interactive, feedback-focused, technology is where the project focused.

Innovation

Clickers

Electronic voting systems, or 'clickers', have become increasingly popular in the HE sector as a means of informal in-class assessment, and instantaneous feedback to both the teacher and student (Draper and Brown 2004, Jisc 2005, Smith and Cogdell 2006, Blasco-Arcas *et al.* 2013). Clickers are typically used alongside Multiple Choice Questions (MCQs) to independently assess students in a formative manner. This style of assessment identifies poor metacognition amongst students as they are encouraged to commit to an answer, rather than playing the role of a spectator in their own

education (Draper and Brown 2004). This commitment to an answer also promotes engagement not only in the assessment process, but also in the subsequent feedback (Wit 2003, Beatty 2005, Beatty *et al.* 2006, Caldwell 2007). Such low stakes assessment provides an early opportunity to identify students who are struggling with core concepts, allowing an opportunity for intervention prior to summative assessment (Lang 2012). Clickers therefore appear to offer a solution to the issues surrounding the lack of feedback and participant interaction in histology practicals.

Are clickers innovative in histology practical sessions?

On commencing this project, clickers had not previously been used in a practical setting within the medical school. The literature detailing the use of clickers in the practical setting is surprisingly sparse considering the potential benefits the use of this technology could offer. Instead, the use of clickers appears to be predominantly restricted to the lecture setting (Draper and Brown 2004, Caldwell 2007). This appears to reflect the static nature of histology practicals as a whole. The adoption of a contingent approach to teaching, with a flexible learning environment, is a relatively modern style of HE teaching where instruction can be modified based upon student feedback (Draper and Brown 2004, Kay and LeSage 2009).

Several factors are likely to affect the adoption of an innovation, and thus must be considered when implementing innovative practice if it is hoped to become embedded practice (Jisc 2005). These factors are outlined in Rogers' characteristics of innovation (blue), and have been applied to the current context (green) in Figure 3. Having considered these factors in the context of histology practicals, it seems plausible that the use of clickers may become an embedded practice.

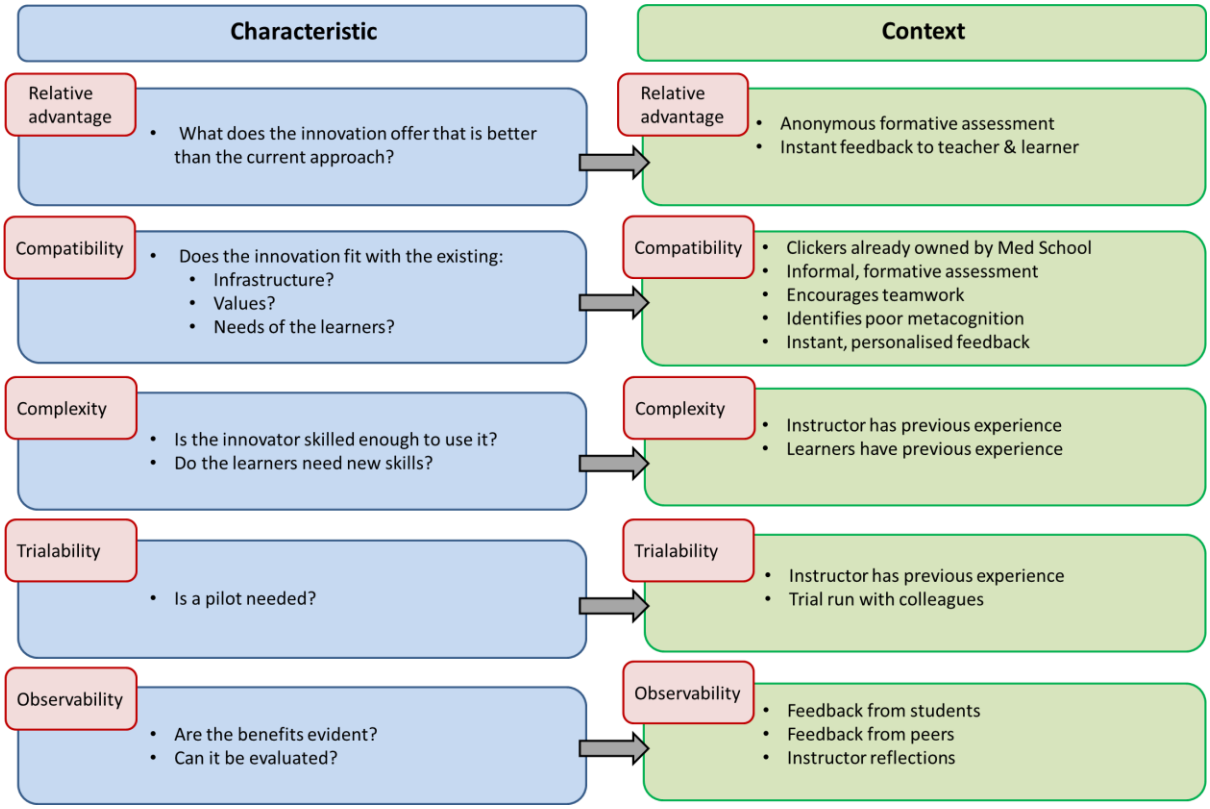

Figure 3: Rogers' Diffusion of innovations (2003) – Adopter Characteristics. The characteristics of different adopter types have been applied to the current context (green). In summary: 1). The advantages are primarily anonymous assessment and feedback for both the student and teacher, 2). The innovation is compatible with the current context, 3). The innovation is not complex as both the teacher and learner have previous experience with the technology, the innovation can be trialled in a test environment, and the outcomes are clearly evident to both staff and learners. This figure has been adapted from Rogers (2003).

Instructional design

Throughout the project a process of instructional design was implemented to ensure that the project was planned efficiently, and met the necessary criteria. For this, the ADDIE (Analyze, Design, Develop, Implement, and Evaluate) instructional design cycle was selected as it promotes evaluation at all stages (Branch 2009). This cycle is applied to the current context in Figure 4.

Clickers had not previously been used in a practical setting within the medical school. The school had, however, purchased Turning Point ResponseCards from Turning Technologies for use within the school. The school currently owns 153 handsets, with an approximate price of £20 per device (internal quote). These units work via radio frequency (RF), on a default channel of 41, however this can be changed to allow the clickers to be used in separate rooms on separate PowerPoint presentations without any interferences from other devices (Caldwell 2007 and TurningTechnologies). The pre-existing availability of this technology ensured that not only were there no financial implications of this project, but also that the students had prior exposure to the equipment, all be it in a lecture theatre setting. In addition, in my previous role as lecturer at another university I had used the TurningPoint system to ask anatomy undergraduate students

MCQ-style questions during lectures. This meant that as the lead for the planned sessions I was in a position where I was proficient in the use of the equipment, and also perhaps more importantly, how it can go wrong.

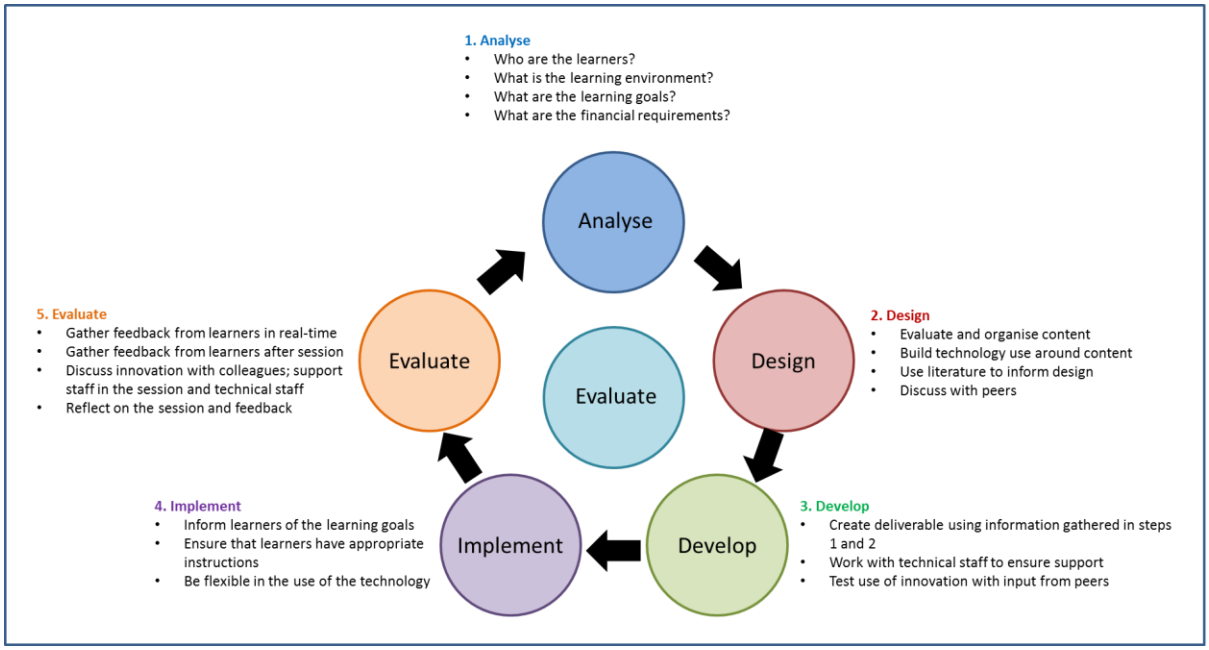

Figure 4: ADDIE model of instructional design

- Stage 1 – The current context and problem are identified. The learners, learning environment and learning goals have previously been detailed in Figure 2. There was no financial nature to the innovation as all the equipment had already been purchased by the University.
- Stage 2 – The session content was organised to meet the learning goals and accommodate the learners and learning environment. The questions were constructively aligned with the session content and learning goals. This was a literature-informed process that was discussed with peers to ensure maximum efficiency.
- Stage 3 – The questions were developed using TurningPoint software and embedded within a PowerPoint presentation. The presentation was then tested in the learning environment to ensure compatibility.
- Stage 4 – The session was run three times, one for each set of students.
- Stage 5 – Feedback was sought from students. Instructor reflected on the session, with input from colleagues.

At each stage the process was evaluated to allow adjustment where necessary.

Histology sessions are ran throughout the first year of the course on an almost weekly basis. These sessions are two hours long and involve the examination of a range of tissues. The trial session was on endocrine gland histology. Fortunately, the students had been introduced to exocrine gland histology the previous semester, and as such this not only ensured that the students had already been exposed to glandular tissue, but it also gave the opportunity to review the material from the previous session, and compare and contrast it to that covered in the current session. Six separate tissues were covered in the session, all falling under the umbrella term of endocrine glands. This large amount of content, combined with the opportunity for review, was one of the major factors in the selection of this session for interactive clicker use. Following the coverage of the material, and in the final 10 minutes of the session, the students were led through a series of MCQ-style questions (example question in Figure 5). To ensure that all students received an equal opportunity to participate in the questions, they were both displayed on multiple screens around the lab, and read out.

The session was delivered three times over the course of a single week, with each session involving approximately 40 students. The software recorded a response rate of between 93 – 100 % (42/42, 38/41 and 40/42). Each session was run in the same format, and all data was recorded. The assessment is anonymous as students are allocated handsets randomly.

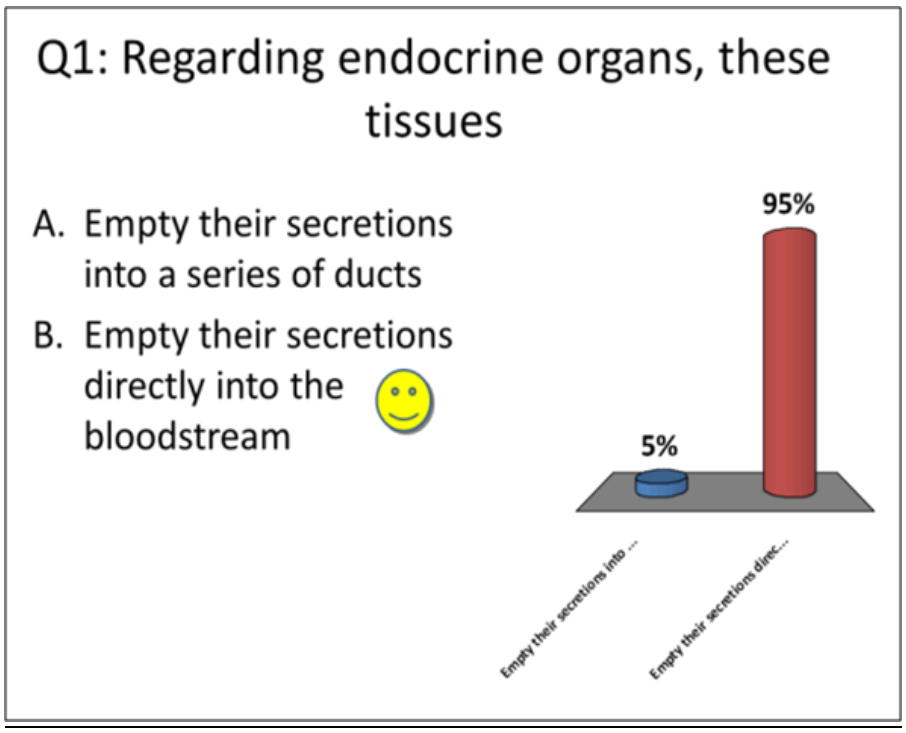

Figure 5: Example PowerPoint slide from the delivered histology session. The TurningPoint questions were fully embedded within the teaching PowerPoint. Results are displayed on the screen for both the learner and teacher to see. Correct answer indicator is shown in the format of a smiley face.

Data collection

Prior to the sessions, ethical approval was sought from the Student Project Ethics Committee. One week after the sessions, students were contacted for feedback on the practical. This was done outside of the session, and an in an electronic format, so as to allow the students time to: consolidate their knowledge from the session, reflect on the impact of the use of clickers, and to provide detailed feedback where necessary.

The survey was created using SmartSurvey (www.smartsurvey.co.uk), a free online survey tool that was more user-friendly and adaptable than others such as SurveyMonkey. A mix of both Likert-style questions and free text boxes were selected to ensure that the survey was quick, but allowed participants to provide more detail if they wished. The survey was limited to 10 questions and the students were assured that it would take them no longer than five minutes to complete. Two participants opened the survey but failed to complete any of the questions. The 10 questions in the survey are shown in Figure 6.

Questions	Options
1. On which day did you attend the Functional Microanatomy practical on Endocrine Organs (Unit 4, week 1)?	A. Monday (Sets A and B) B. Friday (Set C)
2. Did you participate in the MCQ-style quiz at the end of the session?	A. Yes B. No
3. Do you feel that the voting system (clickers) enabled you to test your knowledge from the session?	Likert Scale (Strongly agree→ Strongly disagree, and Other)
4. Do you feel that the voting system (clickers) encouraged you to engage with the material provided in the session?	Likert Scale (Strongly agree→ Strongly disagree, and Other)
5. Would you prefer to use clickers to anonymously answer questions compared to raising your hand?	Likert Scale (Strongly agree→ Strongly disagree, and Other)
6. In functional microanatomy, would you prefer to use clickers to independently answer questions compared to working in group?	Likert Scale (Strongly agree→ Strongly disagree, and Other)
7. Did the quiz allow you to identify any gaps in your knowledge?	Likert Scale (Strongly agree→ Strongly disagree, and Other)
8. Did the length of the answers provided affect your ability to understand and answer the question?	Likert Scale (Strongly agree→ Strongly disagree, and Other)
9. What do you think worked well in the session?	Free text box
10. What could be improved in the session?	Free text box

Figure 6: Electronic survey content. Students were asked to complete 10 questions (blue). The available options for answering these questions are shown in green. In addition to the Likert scale for questions 3-8 free text boxes were also provided to encourage students to comment.

Students from all three sets responded to the survey, however due to the anonymous nature of the electronic questionnaire it was not possible to identify any patterns in the responses from different sets.

The design and implementation of the current project fits all stages of the assessment and feedback lifecycle advocated by Jisc and originally developed by Manchester Metropolitan University (CC 4.0). The lifecycle has been applied to the current context in Figure 7.

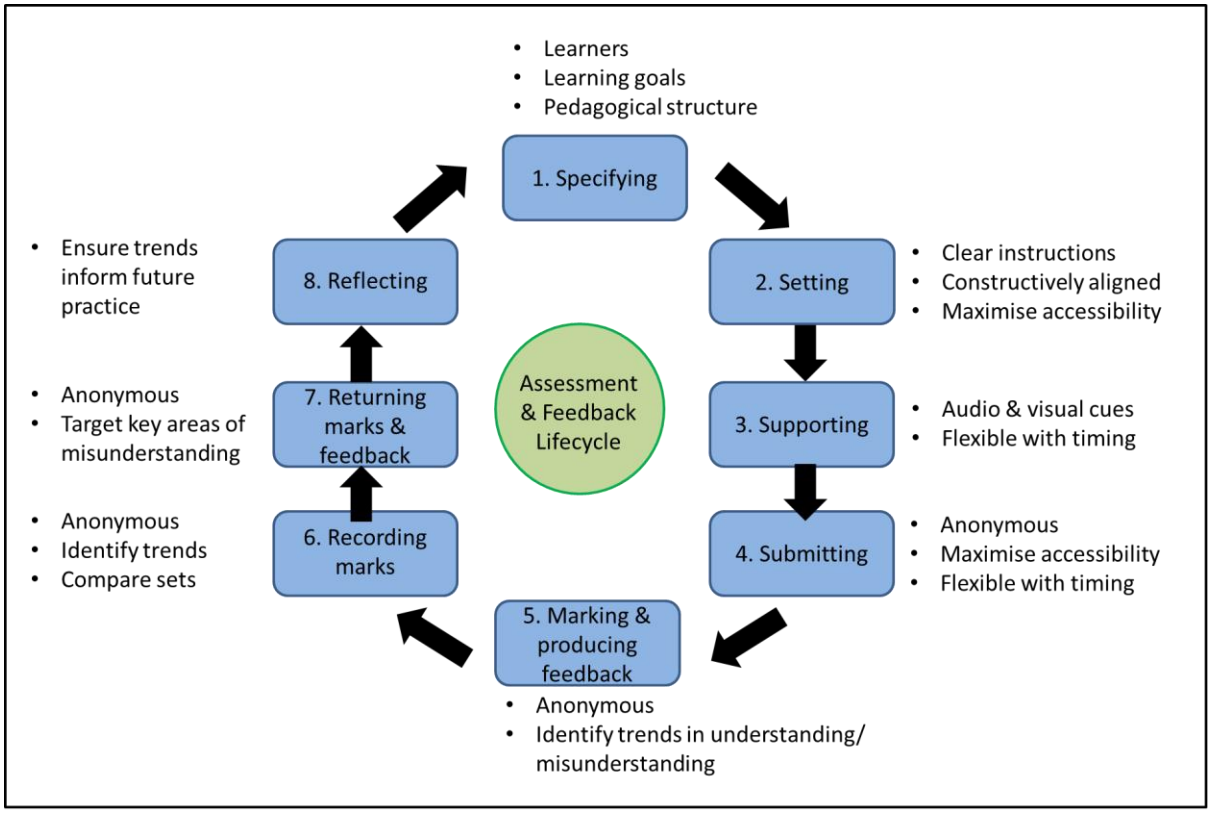

Figure 7: Assessment and Feedback Lifecycle. Inspired by the MMU lifecycle (CC 4.0). The lifecycle has been applied to the current context. The current project fulfils all the stages of the lifecycle in a shortened timespan (matter of minutes). The anonymous nature of the assessment means that records are not kept on individual students but these can be kept for sets of students, and trends can be noted.

Feedback and reflections

Clickers enable students to test their knowledge

All participants responded that the clickers enabled them to test their knowledge from the session (Figure 8). In addition, three students provided written feedback on this aspect of the research. Respondent 16 highlighted that many students appreciate the opportunity to learn from their mistakes and that the formative assessment allowed them to consolidate their knowledge. Similarly, respondent 21 stated that the in-class quiz allowed them to identify areas where they needed to improve their understanding of the subject content. Respondent 20 identified another essential factor in that the content of the session and the in-class assessment were constructively aligned (Biggs 1996 and 2003, Skinner 2009). This almost takes the technology out of the question and focuses on the pedagogy of the session. This student also states that the clickers provide an appropriate tool for the assessment, therefore highlighting how the technology is supporting the pedagogical aim of the session, rather than the session being focused around the technology itself.

This feedback reflects the literature, where researchers use clickers to tackle under-achievement (Hammersmith and West London College case study, Jisc 2005), and improve test results (Crouch and Mazur 2001).

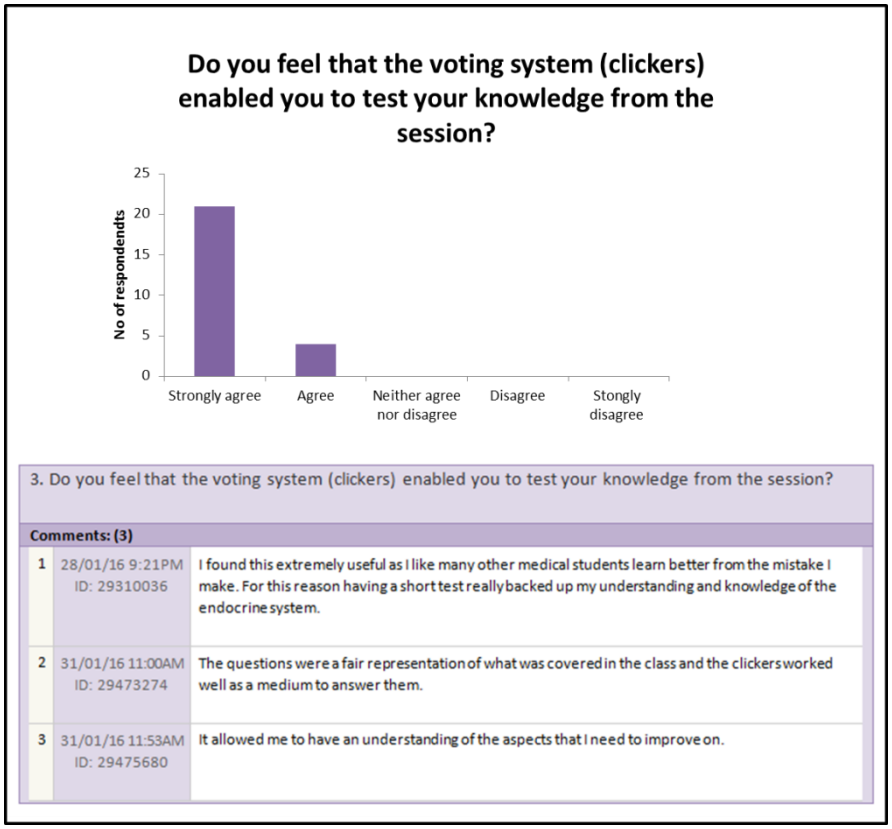

Figure 8: Clickers allow students to test their knowledge. Students either strongly agreed (84%) or agreed (16%) that the use of clickers allowed them to test their personal knowledge of the session content. The second comment highlights how the quiz questions were constructively aligned with the session content. Students noted that it allowed them to identify where they need to focus their learning.

Clickers encourage students to engage with practical session material

96% of students responded that the clickers encouraged them to engage with the content provided in the session (Figure 9). The remaining participant neither agreed nor disagreed. Two students commented on the need for a link between learning and assessment. Respondent 11 noted that knowing that the content would be assessed made them actively learn the material. Respondent 25 also highlighted their desire for a warning of the test. These two comments show the difference between 'assessment *of* learning' and 'assessment *for* learning' (Germany 2015); the former student identified that the test was part of the learning process, whereas the latter student perceived the test as the end point of learning. This is reflected in the literature where Skinner (2009) highlights that when students' answers are marked incorrect, they move to asking *why* they are incorrect – they are learning from the assessment.

Additional comments focus on the session content. The session did contain a large amount of new information for the students. Due to timetabling constraints it is not possible to split the session into two, however, it may be possible to adopt a flipped classroom-style approach. In this format the bulk of the material could be provided online for students prior to the session, and the face-to-face time used to *apply* the knowledge. In addition to promoting higher order learning (Bloom 1956), this format would also provide an opportunity for peer-learning (Crouch and Mazur 2001, Jisc 2005, Caldwell 2007, Lang 2012) and allow the students time to ask questions prior to the in-class formative assessment. The importance of peer-learning is highlighted in the literature where 92% of students agreed that discussing questions with their peers aided their understanding, and 82% stated that this ultimately helped them learn (Caldwell 2007).

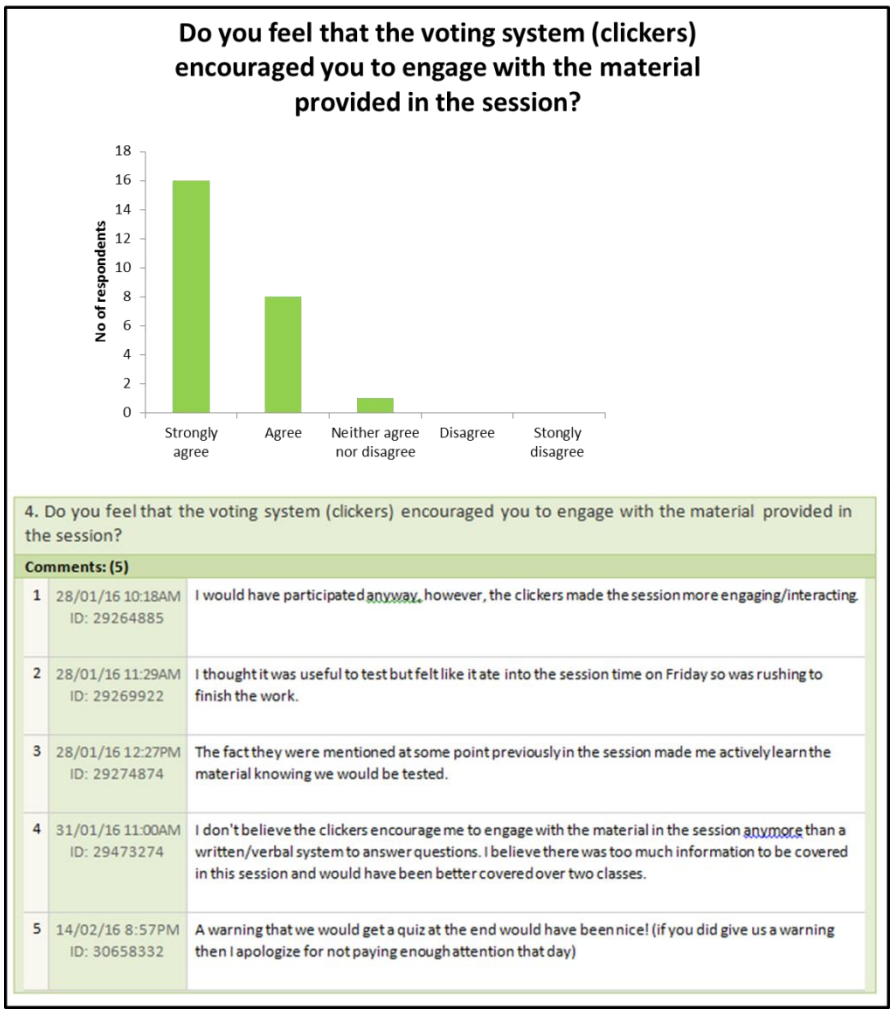

Figure 9: Clickers encourage students to engage with the material. 96% of students stated that the use of clickers encouraged them to engage with the content of the session. One student neither agreed nor disagreed. Two students highlighted concerns about the amount of content in the session. Students appear to require pre-warning of the formative assessment to find it a valuable learning experience.

The anonymous nature of clickers is a key benefit to students

92% of students responded that they would rather use the clickers to answer questions as compared to raising their hands (Figure 10). One student neither agreed nor disagreed, and one student disagreed with the statement. The three comments provided in response to this question all supported the use of clickers, and all either explicitly mentioned, or hinted towards, the benefit of anonymity in assessment. Respondents 10, 20, and 25 reference the embarrassment of failure as a major factor in the reluctance to answer questions in a group setting. Furthermore, respondent 25 also highlighted the tendency of students to answer the same as their peers and thus never actually test their own level of understanding. The benefits of anonymity in formative assessment is evident throughout the literature with Cogdell highlighting how clickers encourage a reticent student to participate without fear of ridicule (Cogdell *et al.* 2012, Smith and Cogdell 2006).

This data indicates that students view the answer selected as the only factor that matters in assessment. In my opinion, however, the *process* by which the student arrives at that answer is just

as important. For example, if a student identifies the tissue incorrectly but is able to justify why they provided that answer then this shows that they understand the material and are attempting to *apply* it to novel scenarios. One way of potentially overcoming this situation is through the 2-hit approach:

1. Students answer a question independently
2. The results are displayed on the screen, but the correct answer is not displayed
3. The students discuss why they selected their answer
4. Students are given a second opportunity to vote
5. The responses are displayed on the screen, alongside the correct answer
6. If necessary, a teaching slide is provided

This approach not only gives the students the opportunity to independently assess their understanding of the content in a non-threatening manner, but the peer discussions also encourage peer learning. Finally, the teaching slide that follows the results ensures that students understand where they have gone wrong, if applicable. This approach is advocated by Alexander (2009) and Lang (2012) in their work on assessments.

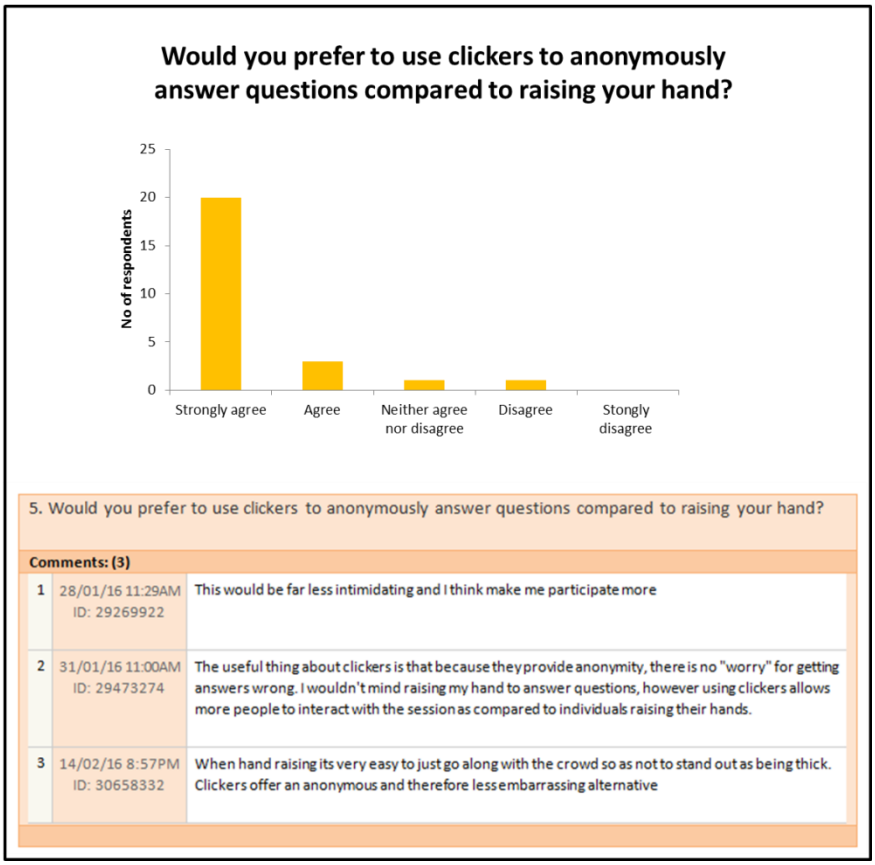

Figure 10: Students prefer to anonymously answer questions using clickers rather than raising their hands. 92% of students preferred the ability to anonymously answer formative questions using the clickers instead of raising their hands. One student neither agreed nor disagreed. One student disagreed. Students note that the clickers are less intimidating and thus encourage participation. Unfortunately the student who disagreed did not provide a comment.

There are benefits to the use of clickers in both group, and independent, assessment

56% of participants responded that they would prefer to use the clickers independently rather than for group assessment (Figure 11). Respondent 7 highlighted that independent assessment simulates summative exam conditions.

40% indicated that they neither agreed nor disagreed with the question, potentially indicating that the use of clickers in either scenario would be beneficial to the student. One student disagreed with the statement, commenting that group work is beneficial in clearing up misconceptions. Perhaps, the 2-hit approach mentioned above would allow both those eager for independent assessment, and those who prefer to work as a team, to benefit from the formative assessment. This feedback is reflected in the literature, where peer-focused discussions are highly praised (Crouch and Mazur 2001, Jisc 2005, Caldwell 2007, Lang 2012).

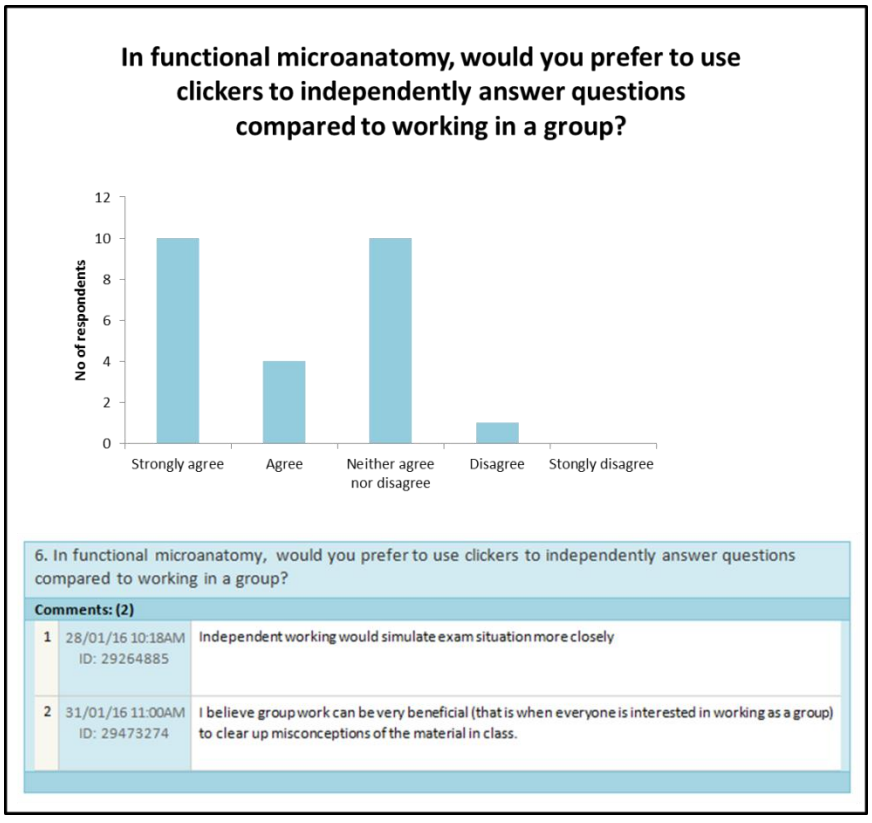

Figure 11: Students see a benefit in the use of clickers for both independent assessment and group work. The majority of respondents (56%) believed the biggest benefit in clicker use lied with independent assessment. These students highlighted how this would replicate exam scenarios. One student thought that clickers were more effective when used for group assessment, highlighting that this allows the clearing up of misconceptions. 40% of students neither agreed nor disagreed. Together, this data indicates that students may benefit from the use of clickers during both independent assessment and group work.

Clickers allow students to identify gaps in their knowledge

96% of students responded that the interactive in-class assessment allowed them to identify gaps in their knowledge (Figure 12). Interactive formative quizzes force the learner to commit to an answer and therefore identify poor metacognition (Draper and Brown 2004). Indeed, this is one of the key benefits of clickers cited in the literature (Caldwell 2007). This approach also provides the opportunity for students to see how they are doing compared to their peers, many seek comfort in knowing that they are not alone even in their misunderstanding (Cogdell *et al.* 2012). Ultimately, clickers empower the learner and therefore allow personalised learning (Jisc 2005).

One student noted the limitation of MCQ-style questions. This reflects how different styles of assessment require different levels of cognition (Anderson 1999). This will be further discussed later.

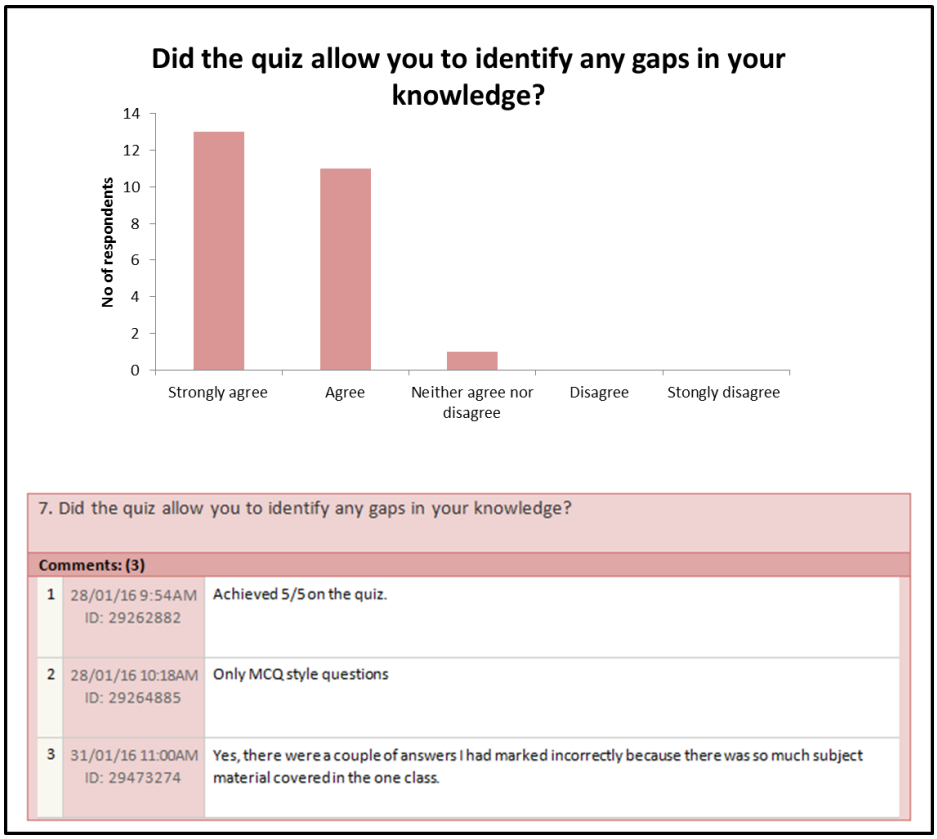

Figure 12: The clicker quiz allowed students to identify gaps in their knowledge. 96% of students responded that the formative quiz allowed them to identify areas where they needed to develop their understanding. One student neither agreed nor disagreed.

Interactive assessment should be inclusive

There were a variety of responses to the question investigating whether the length and/or complexity of the answers affected the participant's ability to understand and answer the question (Figure 13). 40% of students replied that they thought that the length of the answers *did* have an impact on their ability to correctly answer the question. Conversely, 28% thought that this had no impact. One caveat to this was mentioned by respondent 20; as long as the answers are read out properly, the length should not affect the answering capacity. This reflects the different needs of the learner. The literature agrees that questions should be kept short and read aloud to ensure maximal accessibility (Germany 2015). The accessible nature of clickers is one of their major benefits. TurningPoint clickers are specially designed for the visually impaired with Braille characters alongside the corresponding buttons (TurningTechnologies). Furthermore, clickers potentially bypass the social exclusion that may come with the use of mobile phones as a learning tool.

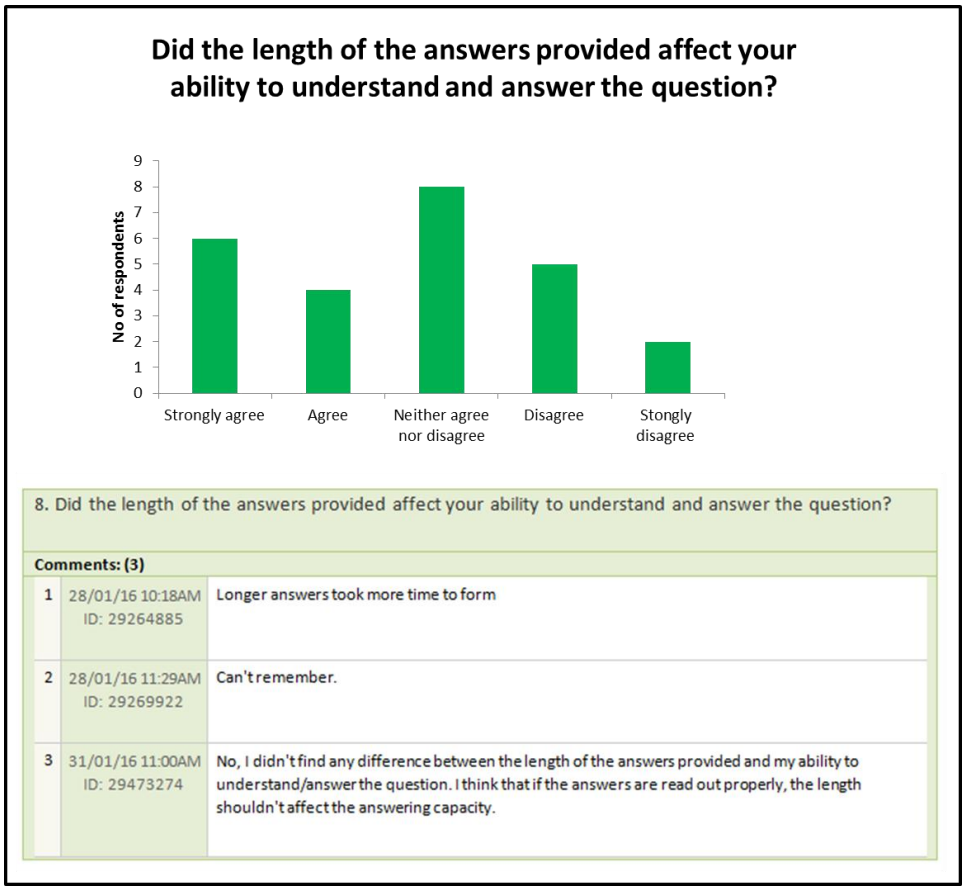

Figure 13: The length of the quiz answers may affect the students' ability to understand the question and therefore select an answer. This highlights the different needs of the learners and therefore reinforces the need for equal learning opportunities for all.

Requirements when using clickers in practical classes

A free text box was provided for question 9; what do you think worked well in the session? Thematic analysis on the comments identified five key areas that worked well during the use of the innovation, these were:

1. Plenty of help and support
2. Well-organised and detailed slides
3. Ability to identify gaps in knowledge
4. Engaging
5. Opportunity to consolidate what was taught, and learnt, in the session

This feedback can be seen in Figure 14. Other comments that appeared less frequently included the interactive and enjoyable nature of the quiz, the opportunity to immediately apply the information learnt, the prevention of embarrassment, and the ability for staff to see areas where students are struggling (white).

The comments regarding the support provided by staff, and the organised and detailed slides, highlight the importance of support for learning. This is reflected in the literature where the support provided by the teacher is the most important factor in the learning experience (Michael 2001, Sherman and Jue 2009).

Perhaps the most enlightening comment is found under the theme of gaps in knowledge (blue, gold star); the ability to assess in your *own* mind how much of the content you actually *learned*. This reflects the shift in focus away from rote memorisation and information transfer to higher order learning where students are able to apply the information learnt to new scenarios (Bloom 1956). This is re-iterated where the student praises the opportunity to immediately *apply* the information (white, gold star). The use of a level three verb from Bloom's taxonomy in this comment highlights the shift to deeper learning. The identification of areas of misunderstanding is frequently highlighted in the literature as a key benefit of clickers (Caldwell 2007).

Students also highlighted the benefits of the instructor identifying areas where students are struggling (white, blue star). This showed that even the students are aware of the need for 2-way feedback. This aspect of the innovation allows the instructor to produce a flexible learning environment that promotes contingent teaching (Draper and Brown 2004, Beatty *et al.* 2006).

Although not explicitly mentioned, the anonymous nature of the quiz also seemed popular. The reference to the lack of embarrassment hints at the benefit of the ability to answer without fear of reprisal. This reflects the feedback from question 5, where 92% of students stated they would prefer to use clickers rather than raising their hands (Figure 10).

Students also praised the way the quiz provided an engaging and constructive summary to the session. This is important when considering the literature states attention may deteriorate after just 20 minutes of didactic teaching (d'Inverno, Davis and White 2003, Jackson *et al.* 2009). One student even went as far as to describe the activity as enjoyable, and indeed this reflects the literature where clicker-use tends to have a 70% approval rating (Draper 2002, Simpson and Oliver 2006).

Overall, it appears that the main considerations when introducing this technology to a practical setting are:

1. The importance of good resources, be it staff, PowerPoint slides, textbooks etc.

2. The constructive alignment of the assessment to both the content of the session, and future summative assessments

3. The ability for feedback to inform current and future practice (contingent teaching)

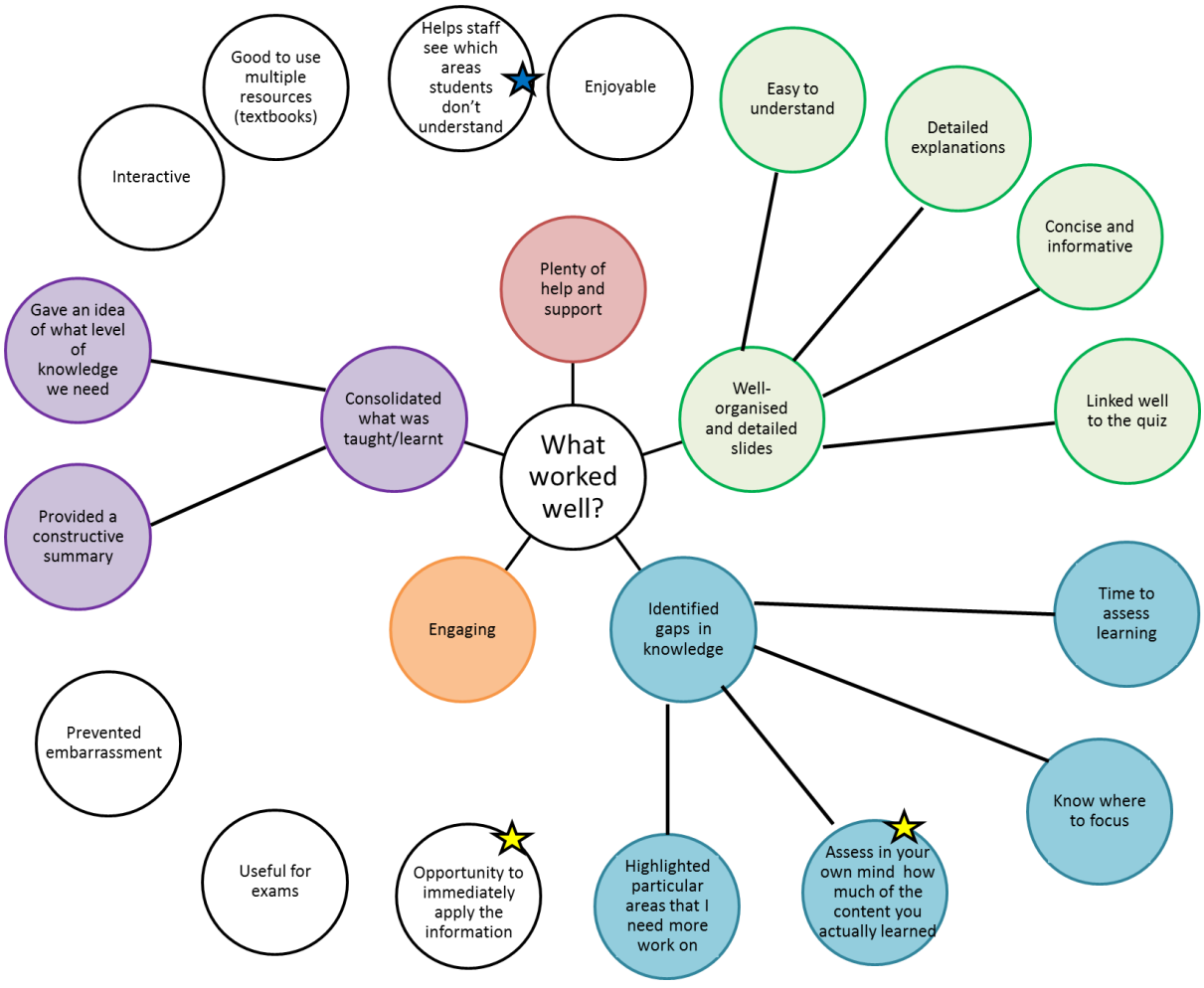

Figure 14: Thematic analysis of free text comments from students. Students were asked to comment on what worked well during use of the innovation. Only one student did not provide any feedback in this section. Five key themes were identified; plenty of help and support, well-organised and detailed slides, identified gaps in knowledge, engaging and consolidated what was taught/learnt. The white circles represent additional comments that were outside of the five key themes.

Areas for improvement in the use of clickers in practical classes

Students were asked to identify what could be improved in the session. Thematic analysis on the comments identified four areas for improvement:

1. More time is needed
2. Less content should be covered
3. Prior exposure to content would aid learning
4. More questions should be asked

This feedback can be seen in Figure 15. As previously mentioned the content within the session was extensive (green). Unfortunately, this was an external factor and something outside of the control of this project. Similarly, the timetable for undergraduate students is controlled by external forces (red). There is, however, scope to manipulate the session in such a way to overcome both of these issues, and the concerns regarding prior exposure to content (blue). The session could be further adapted to become a flipped classroom whereby students receive the content, either all or at least the basics, outside of the classroom setting. This therefore frees up the face-to-face time for hands-on learning with the microscopes, and provides sufficient time for students to apply their knowledge to the context through interactive question and answer sessions. In addition, this makes the session more flexible, with tutors adapting to the level of understanding of the students. Similarly, this would also allow the opportunity for more clicker-style questions (purple). The session could start with some simple interactive questions to assess the students' understanding of the preparatory content (Skinner 2009), followed by trouble-shooting of any problem areas through teaching slides and microscope activities, and concluded with a summary quiz to allow the students to apply their knowledge to novel scenarios. In addition, extended matching questions (EMQs) could be introduced (purple), an innovation that would reflect how different styles of questions require different levels of cognition (Anderson 1999). Together, this shifts the focus to higher order learning (Bloom 1956) that is constructively aligned to the curriculum (Skinner 2009, Biggs 1996). It is worth noting that Elliot (2003) stresses that any reduced content coverage is more than compensated for by the students increased depth of understanding.

Reflecting on the use of this technology, it became apparent that there may be scope for the use of this style of formative assessment throughout the sessions, contrasting to the summary-style of approach detailed here. This would reflect the use of clickers in the literature where they are commonly introduced after a short segment of teaching. This provides the benefit of promoting engagement throughout the session and immediately identifying areas of misunderstanding (Crouch and Mazur 2001, d'Inverno, Davis and White 2003, Jackson *et al.* 2009, Lang 2012). Indeed, this approach was adopted for a subsequent teaching session for year 2 undergraduate medical students on the special senses. This appeared a popular innovation that provided a quick opportunity to review the material before progressing to the next concept. This also overcomes the issues surrounding learner attention spans, which the literature suggests are limited to 20 minutes (d'Inverno, Davis and White 2003, Jackson 2009). This is similar to the pause procedure advocated by Prince (2004), and Di Vesta and Smith (1979).

An additional modification that could be made to the approach is the 2-hit style previously discussed. This encourages students to independently commit to an answer ensuring investment in the outcome, before discussing (and justifying) their answers with their peers, and then re-

answering the question. This promotes thinking about *why* their answer is correct, an approach that inhibits rote learning, and ensures deeper understanding of the content (Bloom 1956). In addition, this also mirrors the peer learning approach advocated by many HE institutions, including Keele (Crouch and Mazur 2001, Jisc 2005, Caldwell 2007, Lang 2012).

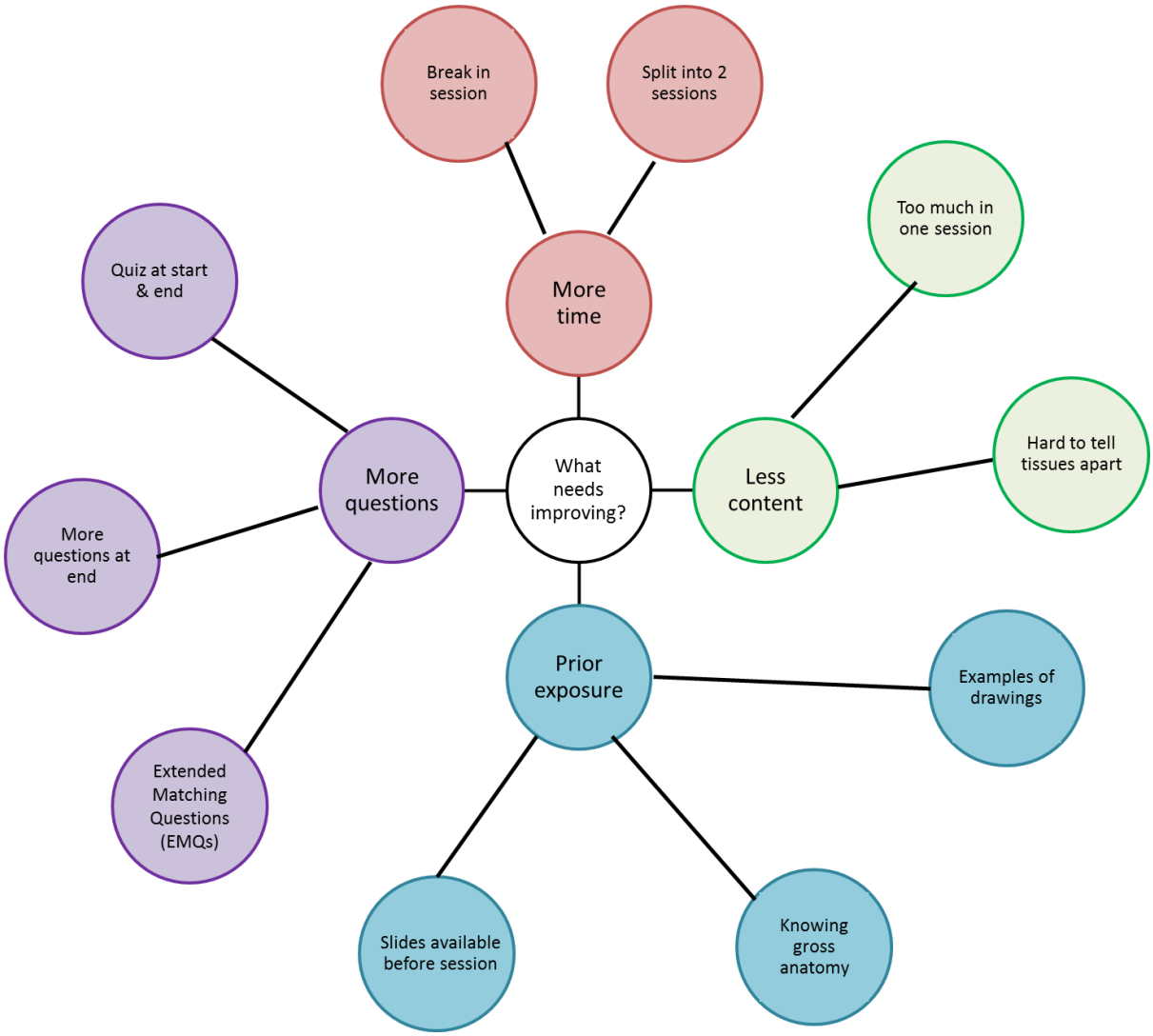

Figure 15: Thematic analysis of free text comments from students. Students were asked to comment on what could be improved during use of the innovation. 40% of respondents either skipped the question entirely, replied 'nothing', or N/A'. Four key themes were identified; More time is needed in the session, less content should be covered in the session, prior exposure to the content would aid learning, and more questions should be provided.

Overall, it appears that the main areas for development when implementing interactive quizzes in a practical environment are:

1. Allow sufficient time for content coverage
    - A flipped approach may be required
    - Students need adequate base knowledge to develop upon

2. Initiate the session with a quiz to link current knowledge with new knowledge
    - Encourages students to build on their existing knowledge

3. Introduce questions after each section of teaching
    - Ensures engagement and attention
    - Immediately identifies problem areas
    - Allows a flexible approach

4. Potentially utilise the 2-hit approach
    - Encourages personal investment in the outcome
    - Provides personalised feedback
    - Promotes the ability to explain *why* that answer is correct
    - Encourages peer-interaction and learning

5. Teaching must be flexible
    - Target areas of misunderstanding
    - Content can be covered outside of class if necessary

At all times it must be remembered that assessment drives learning, and if you want to change the way in which students learn (away from rote memorisation and towards understanding), then the assessment methods must be changed (Brown, Bull and Pendlebury 2013). This style of in-class formative assessment, used in conjunction with additional approaches to learning (motor skills, teacher-led instruction, self-discovery etc.), encourages engagement with all the available learning opportunities (Gibbs *et al.* 2005), and thus promotes equal access to learning for all.

Conclusions

This study provided an opportunity to examine the impact of interactive assessments in practical sessions. The introduction of a clicker-based quiz to a single histology practical session (repeated three times) allowed me to gather feedback from students on their opinion of the use of formative feedback as a means of promoting engagement and testing understanding. This, combined with my own personal reflections, and discussions with colleagues, identified three major themes when introducing interactive formative assessment to practical sessions. The first was the importance of support for learning in, and after, the session. Students noted how they found the assessment beneficial because it was appropriately supported by staff members and detailed visual aids

(PowerPoint slides). This stresses the importance of the tutor-student interactions in the learning process. Secondly, the assessment must not be introduced for assessments sake, it must be constructively aligned both with the content covered in the session, and the summative assessments in the future. Thirdly, my own personal experience of the sessions, in particular, highlighted the need for the tutor to be flexible in the use of such an innovation. It is quite likely that the responses to a question may require a change to the content covered, or the amount of time spent on a specific area. Although many may see this as a daunting possibility, this is something to be embraced as it tackles poor understanding early on, and it ensures both student and teacher are fully invested in the learning process.

In summary, clickers provide an accessible means of formatively assessing students and providing immediate feedback to both the student and teacher (Smith and Cogdell 2006, Alexander *et al.* 2009, Kay and LeSage 2009). Furthermore, the anonymous nature of the clickers encouraged engagement with both the assessment, and the material in the session. Clickers appear to provide a simple means of encouraging higher level learning where students are encouraged to ask 'why?'. Finally, when considering any innovative teaching practice it is important to remember that it may not improve grades, but if it encourages students to enjoy learning then that, as far as I am concerned, is a success.

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