

Luke E. Grzeskowiak, Alice E. Thomas, Josephine To, Adam J. Phillips, Emily Reeve
Enhancing education activities for health care trainees and professionals using audience response systems: a systematic review

Journal of Continuing Education in the Health Professions, 2015; 35(4):261-269

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This is a non-final version of an article published in final form in *Journal of Continuing Education in the Health Professions*, 2015; 35(4):261-269

Final version available at: <http://dx.doi.org/10.1097/01.CEH.0000473130.55806.87>

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14 March 2018

Enhancing Practice Based Education of Healthcare Professionals Using Audience Response Systems: A Systematic Review

Luke E Grzeskowiak, Alicia E Thomas, Josephine To, Adam J Phillips, Emily Reeve

Luke E Grzeskowiak, PhD, GCertClinEpi, BPharm (Hons) The Robinson Institute, The University of Adelaide, Adelaide, South Australia, Australia & SA Pharmacy, Flinders Medical Centre, Bedford Park, South Australia, Australia

Alicia E Thomas, BPharm, SA Pharmacy, Repatriation General Hospital, Adelaide, South Australia, Australia; Alicia.Thomas@health.sa.gov.au

Josephine To, BPharm, School of Pharmacy and Medical Sciences, University of South Australia, Adelaide, South Australia, Australia; Jo.To@unisa.edu.au

Adam J Phillips, BPharm (Hons), BSc, Good Health Choices, Chemplus Pty Ltd, Adelaide, South Australia, Australia; ajphillips@gmx.com

Emily Reeve, BPharm (Hons), School of Pharmacy and Medical Sciences, University of South Australia, Adelaide, South Australia, Australia & Department of Clinical Pharmacology, Royal Adelaide Hospital, Adelaide, South Australia, Australia; Emily.Reeve@mymail.unisa.edu.au

Corresponding Author:

Luke Grzeskowiak

The Robinson Institute, The University of Adelaide

Lyell McEwin Hospital

Haydown Road

Elizabeth Vale, 5112

South Australia, Australia

T: +61 8 8133 2133

F: +61 8 8182 9337

E-mail: Luke.Grzeskowiak@adelaide.edu.au

Word Count:

Abstract: 240

Main Text: 3479

Running Head: Systematic Review of Audience Response Systems

Conflict of interest

The authors report no conflicts of interest

Author Contribution

LEG, AET, JT and AJP conceived the review and were involved in obtaining funding. LEG and AET were involved in undertaking the literature review and analysing associated data.

LEG drafted the manuscript and AET, JT, AJP and ER were involved in revising it

critically for important intellectual content. All authors had final approval of the submitted and published versions.

Enhancing Education Activities for Practising Healthcare Professionals Using Audience Response Systems: A Systematic Review

Running Head: Systematic Review of Audience Response Systems

ABSTRACT

Introduction: This review examines the effect of incorporating clickers within practice based education sessions on educational outcomes of healthcare trainees and professionals.

Methods: A systematic literature review was conducted on primary research studies published up until August 2014. Studies were identified by database searching (Ovid MEDLINE, EMBASE, CINAHL, Scopus, Web of Science, and PsychInfo), citation searching and reference list checking. Studies were restricted to those evaluating the use of clickers as part of the provision of postgraduate education or continuing education programs, and were evaluated according to Kirkpatrick's four levels of training evaluation (reaction, learning, behaviour and results).

Results: Seventeen studies met the eligibility criteria. Twelve studies assessed learner and/or speaker reactions, with feedback overwhelmingly positive in all studies. Reported learner benefits included increased attentiveness, engagement and enjoyment of presentations. Speakers reported that using clickers engaged the audience and assisted in assessing audience comprehension. Eight studies assessed learning outcomes. Higher level evidence obtained from four randomised studies demonstrated significant improvements in knowledge with the use of clickers compared to traditional didactic presentations, but no differences when clickers were compared to an interactive lecture with integrated questions. No studies adequately assessed higher-level educational outcomes (behaviour and results).

Conclusion: While the use of clickers improves learning environment and learner satisfaction, the limited high quality data for improvements in learning and behavior

outcomes make it uncertain whether the acceptance and implementation of clickers within routine practice based education programs is warranted at this stage.

Manuscript

Introduction

Significant potential exists in using Audience Response Systems (referred to herein as clickers) to enhance the provision of education material for practising healthcare professionals.

Clickers are an electronic tool, which enables participants to answer multiple-choice questions (MCQs) during a presentation.¹ The system consists of a personal keypad assigned to each user that transmits answers to a central tabulating system. Responses are collated instantaneously and are displayed graphically on screen, enabling participants to anonymously assess the accuracy of their answer and compare their performance with that of the group. The presenter is also able to see responses and can further discuss questions to ensure all audience members fully comprehend the content.

In the context of this manuscript, education activities for practising healthcare professionals refers to the provision of graduate medical education (e.g. as occurs as part of medical resident training) and continuing education (CE) provided in the postgraduate setting. While differences exist in the final objectives of graduate medical education and continuing education, where one aims to work towards the achievement of certain standards of practice (commonly assessed through an exam) and the other works towards maintaining standards of practice (commonly assessed through recertification and/or reaccreditation

standards), efforts to improve education programs are of great importance. Despite such importance, observations among many professional settings demonstrate a heavy reliance on didactic lectures, despite the known lack of effectiveness of didactic lectures in improving knowledge and supporting practice change.³

The use of clickers has been well researched and extensively utilised within undergraduate student settings for a number of years, with demonstrated benefits over traditional didactic lectures.¹ In these settings clickers have been proven to support key learning principles by promoting learner interactivity, enjoyment, application of knowledge, commitment to an answer, prompt formative feedback and opportunities for reflection on knowledge.⁴⁻⁶ These features have been shown to increase information retention and promote 'deeper' approaches to learning.⁵ Whether these benefits translate beyond the undergraduate setting is of particular interest, given the requirement for efficient and effective methods of learning in the busy practice setting.

While there have been a number of previous reviews on the use of clickers within health professions education^{1, 7-9}, these have predominantly focused on use in the undergraduate setting, with none focused on the practising healthcare professional setting, where approaches towards learning and educational outcomes may differ. In particular, education activities for practicing healthcare professions could be considered as distinct from education provided in the undergraduate settings in that the workplace becomes the classroom and the learning is being undertaken by practising healthcare professionals alongside their busy clinical workload, placing increasing demands on both their attention

and time. This, together with the fact that practising healthcare professionals are adult learners, means that educational activities likely to benefit them most are interactive methods of teaching, providing an engaging environment in which knowledge can not only be learnt but also applied.² Furthermore, these reviews have largely focused on knowledge-based outcomes generated from controlled studies, rather than the evaluation of all available literature. . In addition, the most recent systematic review included studies published up until and including 2010⁷, with the likely emergence of new literature since then providing impetus for an updated review.

Therefore, the aim was to examine the effect of incorporating clickers within education sessions for practising healthcare professionals on educational outcomes, as compared to alternative presentation approaches, through a systematic literature review of all available studies.

Method

Eligibility Criteria

Types of studies: All clinical studies evaluating and providing primary data on educational outcomes associated with the use of clickers within presentations. No language, publication date, or publication status restrictions were imposed.

Types of participants: Practising healthcare professionals (e.g. pharmacists, doctors, nurses) receiving education within practice settings (e.g. hospitals, conferences). Studies solely involving undergraduate students were excluded.

Types of intervention: Studies evaluating educational outcomes associated with the use of clickers as part of the provision of postgraduate education or continuing education programs. Studies where clickers were used purely as a data collection tool, rather than being directly evaluated, were excluded.

Types of outcome measures: Learner and speaker reactions to the use of clickers (e.g. satisfaction surveys, attendance during educational settings), learning effects (e.g. differences in knowledge or skills), and behavioural or practice outcomes (e.g. practical application of knowledge or skills).

Data Sources

The following databases were searched from inception to 20 August 2014: Ovid MEDLINE, EMBASE, CINAHL, Scopus, Web of Science, and PsychInfo.

Search

The search terms used were clicker* OR 'audience response system' OR 'wireless response system' OR 'electronic voting system' OR 'personal response system' OR 'interactive voting system' AND medic* OR nurs* OR physician* OR health OR dentist* OR pharmac* OR doctor* OR dietician* OR psychologist* OR clinic* OR therapist*. In addition, reference lists and citation reports of identified articles were searched (using Scopus and Web of Science) to identify further relevant studies.

Study Selection

Eligibility assessment was performed independently in an unblinded standardised manner by two authors. Disagreements regarding eligibility were resolved by discussion; if no agreement could be reached, it was planned a third author would decide.

Data Collection Process

Data extraction was undertaken by one review author and individually checked by a second author. Disagreements were resolved by discussion between the two review authors; if no agreement could be reached, it was planned a third author would decide.

Data Synthesis

Details of the studies, including study design, number and type of participants, details of intervention and comparison group, summary of study outcomes, and limitations were compiled, with frequency tables used to summarise the studies' results. Studies were stratified according to whether they were controlled or non-controlled studies. Controlled studies included randomised controlled trials, pseudo-randomised controlled studies, and non-randomised controlled studies (e.g. use of historic controls or interrupted time series design). Non-controlled studies included cross-sectional surveys and case series (i.e. in which a single group of subjects are exposed to the intervention alone).

To ascertain the validity of eligible controlled studies, we utilised the Cochrane risk of bias tool to evaluate various methodological components for which there is empirical evidence for their biasing influence on the estimated of an intervention's effectiveness.¹⁰ This includes components such as random sequence generation, allocation concealment,

blinding, incomplete outcome data, selective outcome reporting and other possible sources of bias. These assessments were undertaken independently by two study authors, with no disagreements in reporting evident.

Effectiveness of clickers were evaluated in accordance to Kirkpatrick's four level model of training evaluation.¹¹ In brief, Kirkpatrick's model was developed as a sequential approach towards evaluating training programs and consists of the following four levels; reaction, learning, behaviour and results.¹¹ The first level, *reaction*, involves evaluating how participants feel about the training. The second level, *learning*, incorporates assessment of the resultant improvement in knowledge and/or skills. The third level, *behaviour*, comprises of measuring the practical application of knowledge and/or skills. The fourth and final level, *results*, appraises overall outcomes that have resulted from participation in the training program.¹¹

Included studies were grouped according to Kirkpatrick's four levels of training evaluation (where a single study evaluated 2 different levels they were included in both groups). We then performed a descriptive analysis of the results of the included studies in each of the 4 groups.

Results

Summary of identified studies

The literature search identified 1281 abstracts of which 642 unique abstracts were screened to assess eligibility (**Figure 1**). A further 615 abstracts were excluded following

the initial screen, based on either not meeting the eligibility criteria (N=614) or reporting on the same study (N=1). A total of 27 full-text articles were assessed for eligibility, with a further 10 excluded. This left a total of 17 eligible studies in the qualitative synthesis of this systematic review.

Seven studies were classified as being controlled studies, which included 3 randomised controlled trials (RCTs), 1 pseudo randomised controlled crossover study, and 3 non-randomised non-concurrent controlled studies (**Table 1**). A further 10 studies were classified as being non-controlled studies, which included 1 cross sectional survey, and 9 descriptive case series (**Table 2**). Eight of the studies involved the evaluation of clickers as part of postgraduate education programs solely for medical residents^{2, 12-18}, also accounting for 6 out of the 7 controlled studies.

Impact of clickers on educational outcomes

When the 17 studies were evaluated according to Kirkpatrick's four level model of training evaluation, 11 involved assessment of effectiveness in terms of *reactions*^{2, 12, 14, 15, 17, 19-25}, 8 evaluated *learning*^{12-16, 18, 20, 26} and 1 *behaviour*²⁷ (**Table 3**). The results at each of these levels are described in more detail below.

Level One: Reactions

The majority of studies assessed *reactions* to the use of clickers, with learner feedback overwhelmingly positive.^{2, 12, 16, 17, 19-21, 23, 24, 27, 28} Reported benefits included

increased attentiveness, engagement and enjoyment of presentations. Additional reported benefits included ability to answer questions anonymously and compare answers to their peers, creating a safe environment that was highly valued by participants.^{17, 21, 23, 24}

Of the three studies evaluating speaker satisfaction, all detailed positive experiences, with speakers reporting that using clickers engaged the audience and was useful in assessing audience comprehension.^{20, 21, 23} Speakers also were highly in favour of using clickers again in future presentations.^{20, 21, 23}

Level Two: Learning

Eight studies assessed *learning* outcomes associated with using clickers.^{12-16, 18, 20, 26} Four of these studies included participants being randomised to either the control or intervention, with the remaining four studies including the use of non-concurrent controls^{14, 15, 18} or no control group²⁶. Of the four randomised studies, two compared quiz scores of participants in clickers versus traditional didactic lectures, demonstrating statistically significant improvements both immediately post-presentation¹⁶ and/or at 6-12 weeks follow-up.^{12, 16} The remaining two studies compared the use of clickers to an interactive lecture with integrated questions, finding no significant differences in knowledge outcomes between groups.^{13, 20} Of interest, one of the randomised studies which compared 3 different lecture types (clickers, non-clicker interactive and didactic) found statistically significant differences in learning outcomes between the use of clickers compared to traditional didactic lectures but no differences were evident in comparison to the control interactive group (which consisted of an interactive presentation with embedded questions).¹³ All three

non-randomised controlled studies which evaluated learning outcomes demonstrated significant improvements in knowledge in the intervention group, in relation to the identified controls.^{14, 15, 18} In addition to these studies, one case series described significant improvements between pre- and post-education test scores with the use of clickers as part of an interactive teaching session.²⁶

Level Three: Behaviour

Of the seventeen studies reviewed, only one study evaluated the effect of clickers on behaviour change. It did not, however, employ adequate methods to detect any differences in behavioural outcomes. The study involved a series of clicker presentations delivered to medical doctors and pharmacists describing the new hospital wide anticoagulation guideline. A review of prescribing practice (i.e. adherence to the guideline) was conducted 5 months after guideline implementation. They defined success of the intervention as 75% adherence to guideline at this time. Guideline adherence was found to be 51%, and therefore the intervention was considered unsuccessful. However, as no baseline data was collected on prescribing practice prior to the clicker presentation, the true effect of the intervention on behaviour change was unable to be measured.²⁷

Level Four: Results

None of the seventeen studies reviewed assessed the impact of clickers on resultant patient outcomes. While the previously discussed study had the potential to assess this aspect in the context of an anticoagulation guideline implementation, most patients were

discharged from hospital prior to achieving a therapeutic INR and therefore patient specific outcomes were not able to be evaluated.²⁷

Discussion

Evidence obtained from the seventeen studies identified in this systematic review suggests that well-designed educational programs for practising healthcare professionals incorporating clickers are likely to increase interactivity, learning motivation, cognitive involvement, attendance and enjoyment. The limited high quality data for improvements in learning and behavior outcomes and absence of results outcomes, however, challenges the routine acceptance and implementation of clickers into everyday educational programs.

While this represents the first systematic review focused on the use of clickers within education activities for practicing healthcare professionals, the findings remain consistent with that of previous reviews undertaken in broader educational settings, including undergraduate education of healthcare professionals.^{1, 7-9} A consistent finding across these reviews is the fact that it appears likely that many of the identified benefits of clickers in relation to learning outcomes may stem from the effectiveness of using clickers to improve interactivity, rather than clickers themselves. That said, given their usefulness in promoting interactivity, and the additional benefits they provide in relation to learner and speaker satisfaction, the use of clickers may still play an important role in enhancing education activities for practising healthcare professionals.

There is also a suggestion that the impact of clickers may differ depending on the educational context in which they are used, with a 2012 systematic review observing trends

towards greater effects of clickers on learning outcomes in health professions education when used in the postgraduate/workplace setting compared with the undergraduate setting.⁷ The authors of this review suggest that differences in learning outcomes could be the result of the increased engagement and interactivity associated with the use of clickers in a setting where sleep deprivation and subsequent difficulties with attention are common.⁷ In the context of our findings and updated review, however, it is likely that these benefits relate to all interactive modalities, rather than clickers specifically, as no differences are apparent when clickers are compared to interactive presentations.

Limitations of identified studies

For each of the seven controlled studies we individually assessed the risk of bias,¹⁰ with all assessed as being at high risk of bias in relation to at least one key aspect of the study methodology such as selection bias or attrition bias (**Supplemental Table 1**). Other sources of bias were also evident including variability of speakers used to deliver presentations, inconsistencies in the content of the presentation given in the intervention and control groups, and the use of different tests/exams used to compare learning outcomes between the groups (**Table 1**). Additional potential sources of bias were also evident across the remaining studies (**Table 2**), with the most evident being the absence of any comparison group, which is essential in attributing outcomes to the intervention being studied. That said, while this would no doubt impact on the evaluation of outcomes such as differences in knowledge, one could argue about the likely bias this may have on evaluating the quality of responses to questions evaluating learner or speaker satisfaction with clickers.

For many, they would provide their own internal comparison as to their experience of using clickers to that of previous presentations they have attended where clickers have not been used. Given all studies evaluating reactions reported positive outcomes it is unlikely that more rigid study designs would alter these findings.

The evaluation of learning outcomes appears to be the subject of greater bias associated with the included studies. Of the four randomised studies, two compared test scores of participants attending interactive presentations incorporating the use of clickers compared to non-interactive presentations (didactic lectures) which did not include clickers.^{12, 16} The fact that the intervention consisted of two components, being the inclusion of MCQs to make them interactive and the use of clickers, makes it impossible to attribute the observed differences to the use of clickers alone. The two remaining randomised controlled trials which compared the use of clickers to an interactive lecture with integrated questions and found no significant differences in learning outcomes between groups may have been influenced by bias associated with the use of different speakers across the interactive and control presentations (which may have led to inconsistency in the delivery of the presentations),²⁰ and the potential for attrition bias with different levels of attendance at presentations across each of the groups¹³. Moving beyond these studies, while all three non-randomised controlled studies which evaluated learning outcomes demonstrated significant improvements in knowledge associated with the use of clickers,^{14, 15, 18} each of these studies suffered from significant limitations in relation to either differences in the exams used to evaluate knowledge outcomes across groups^{14, 15} or the introduction of a multi-factorial intervention in which the use of clickers represented

just one component¹⁸. In addition to these studies, one case series described significant improvements between pre- and post-education test scores with the use of clickers as part of an interactive teaching session, however, the absence of any control makes it impossible to assess any increase in knowledge associated with the use of clickers above that of what would be expected by just attending the session in the first place.²⁶

Integration of clickers within education activities for practising healthcare professionals

Benefits

Based on identified studies, well-designed education programs for practicing healthcare professionals incorporating interactive methodologies have demonstrated potential to increase interactivity, learning motivation, cognitive involvement, attendance, enjoyment and improve knowledge retention. While these studies provide consistent evidence of improvements in learner enjoyment and engagement following the use of clickers, it is unclear whether these represent short-term or long-term effects. While it is possible that reported benefits relate solely to the novelty of this technology, one study reported a sustained increase in attendance to seminars of 50% over two years following the introduction of clickers as part of their routine education program, demonstrating that effects of clickers on learner satisfaction and attendance may persist long-term.² As such, improved interactivity through use of clickers may well translate into improved long-term education outcomes.

Ultimately, the use of clickers represents an innovative educational tool that may assist practising healthcare professionals in not only becoming more efficient, effective and

engaged learners but also better educators, given positive outcomes relating to speaker reactions reported to date. Additional benefits of clickers include the anonymous and systematic manner in which responses are collected during presentations. These responses can be utilised by presenters to evaluate participant's knowledge of the topic being presented, enabling them to modify their presentation to suit the needs of their audience.

Challenges

Based on the identified studies, a number of challenges are evident regarding use of clickers as part of routine education programs for practising healthcare professionals. The most evident of these is the associated cost of the technology²⁰, which includes an initial large outlay for individual clickers, receiver and associated software (which can cost up to \$2,000 for a set of 30 clickers). Ongoing costs are associated with replacement of batteries and clickers. Of note, cost may become less of an issue with the introduction of smartphone applications, which allow participants to utilise their smartphones in place of a keypad to participate in the presentation. This still requires the purchase of a receiver, but carries with it the benefit of limited outlay and no ongoing expenditure. New technologies also allow for the use of a hybrid model, allowing the concurrent use of smartphones and clickers, catering for all participants.

An additional challenge involves presenters being familiar with the technology and being willing and able to incorporate questions into their presentations. This technological challenge was evident in at least one of the included studies where speakers felt that they were not adequately trained in how to use the clickers and that it was time consuming to

incorporate clicker questions into their presentations.²¹ In light of this, the development of high quality questions can prove challenging. This may require the development of support materials to assist presenters if clickers are to be implemented successfully. Additionally, despite increased interactivity and ease of use, participants still need to be willing and able to participate during presentations. Lastly, technical difficulties can arise (i.e. flat batteries, receiver error) that interfere with the ability to record participant responses.

Limitations of this review

A common limitation of systematic reviews and source of potential bias relates to limitations in the original studies contained within it. This review is no exception, with the major limitation relating to the overall lack of high-quality studies of sufficient size, with evidence frequently considered to be at high risk of bias. Thus this makes it difficult to generate firm conclusions regarding the value of clickers as part of education activities for practising health care professionals.

While the lack of a formal meta-analysis may be considered a limitation, we did not feel that a meta-analysis of the identified studies would provide a meaningful summary as the small number of identified studies did not appear to be sufficiently homogenous in terms of participants, interventions, and outcomes. For example, significant differences existed across studies in relation to the way in which clickers were incorporated into presentations, the choice of comparison group, and the choice and timing of outcome assessment.

Conclusion

Based on current evidence, the use of clickers as part of education activities for practising healthcare professionals is associated with improved interactivity, learning motivation, cognitive involvement, attendance and enjoyment, but not learning outcomes. It remains unclear whether improvements in learner and speaker satisfaction alone are sufficient to warrant the acceptance and implementation of clickers within routine education programs. As such, further research is required to address current gaps in knowledge, including the evaluation of long-term learning outcomes, impact of learning on behaviour change and professional practice and ultimately, resultant impact on patient health outcomes.

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Table 1: Summary of Controlled Studies Evaluating the Use of Clickers Amongst Practising Healthcare Professionals

Citation	Participants (N)	Study Evaluation	Summary of Results	Limitations
Randomised Controlled Trial				
Miller et al. 2003 ²⁰	Various healthcare professionals (283)	Impact of clickers used as part of interactive presentations (involving MCQs interspersed throughout presentation) on knowledge, and learner and speaker satisfaction, compared with an identical presentation given with MCQs answered through soliciting verbal responses instead of using clickers	<p>Learning Outcomes: Post-presentation knowledge test scores (mean±SD) did not differ between clicker and non-clicker groups (3.9±1.3 vs 4.3±1.3; p=0.129).</p> <p>Learner Reaction: Compared to non-clicker group, those who used clickers rated the presentation higher (scale of 1 to 5, higher score indicating more positive opinion; mean±SD) in relation to overall quality (4.0±0.53 vs. 3.9±0.46; p=0.025), speaker quality (4.1±0.50 vs. 3.9±0.47; p=0.030), and the ability of the presenter to maintain attention and interest (4.4±0.66 vs. 4.2±0.72; p=0.036).</p> <p>Speaker Reaction: Using the same scale, speakers rated the clickers highly in relation to ease of use (4.58), ability to enhance audience attention (4.75), ability to facilitate audience learning (4.45), improved overall quality of the lecture (4.17), and preference to use it again in subsequent presentations (4.45).</p>	Variability in speakers giving presentations
Pradhan et al. 2005 ¹²	Obstetrics & gynaecology residents (17)	Impact of clickers used as part of interactive case-discussion presentation on retention of knowledge 6 weeks later and learner satisfaction, compared with the same material delivered in a standard didactic format	<p>Learning Outcomes: Difference between pre-test and post-test knowledge scores (6 weeks later) greater in intervention (78% to 95%) than control group (80% to 82%; p=0.018).</p> <p>Learner Reaction: All participants found the clickers easy to use, with 82% stating they thought that clickers were a helpful learning aid.</p>	Differences in outcomes could be related to interactivity of presentation, rather than use of clickers alone
Rubio et al. 2008 ¹⁶	Radiology residents (22)	Impact of clickers used as part of interactive presentation (incorporating 5 MCQs interspersed throughout the presentation) on knowledge immediately following the presentation at 3-months later, compared with the identical presentation material delivered in traditional didactic format	<p>Learning Outcomes: Test scores significantly higher among intervention group both directly after the presentation (76.4±16.9% vs. 60.0±19.0%; P=0.02) and at the 3-month follow-up evaluation (58.2±19.4% vs. 27.5±11.6%; P<0.001).</p>	Control group presentation did not include same MCQs as clicker presentation, meaning differences could be unrelated to the use of clickers
Pseudo-randomised Controlled Crossover Study				

Schackow et al. 2004 ¹³	Family medicine residents (24)	Impact of clickers used as part of monthly resident education sessions (with MCQs interspersed throughout the presentation to promote discussion) on test scores immediately post-presentation and 1-month later, compared with identical presentations delivered in either a traditional didactic style (which did not include MCQs), or an interactive style using the same MCQ slides, but without the use of clickers	Learning Outcomes: Immediate post-presentation test scores (maximum score 7, mean±SD) were 4.25±0.28 (61% correct) with non-interactive lectures, 6.50±0.13 (93% correct) following interactive lectures without clickers, and 6.70±0.13 (96% correct) following clicker lectures. Difference in scores following clicker or interactive lectures compared to non-interactive lecture was significant (P<0.001), but no difference between clicker and interactive lectures (P=0.31). No differences observed in 1-month follow-up test scores following interactive lectures without clickers (4.22±0.37), and clicker lectures (5.07±0.34; P=0.11).	Subject allocation non-random and there was not 100% attendance of participants in the respective comparative crossover session
Non-Randomised Controlled/Comparative Study				
Arneja et al. 2009 ¹⁴	Plastic surgery residents (10)	Impact of clickers used to deliver MCQs as part of pre- and post-tests during monthly review sessions for the first half of the year on half-year test scores and learner satisfaction, compared with traditional pencil-paper testing used among the same group for the second half of the year	Learning Outcomes: Half-year test scores higher at the end of the intervention phase, than control phase (85% vs. 75%; p=0.01). Learner Reaction: Compared to pencil-paper testing, the majority of participants enjoyed clicker testing more (60%), and thought that clicker sessions were more interesting and focused (70%).	Half-year cumulative tests consisted of different questions in each time period, with scores likely to vary with difficulty of questions, independent of intervention.
Sharma et al. 2010 ¹⁵	Emergency medicine residents (59)	Impact of clickers used as part of weekly review sessions (with MCQs integrated within presentations to promote discussion) on quarterly exam scores and learner satisfaction, compared with historic controls from the previous year prior to the intervention	Learning Outcomes: Exam scores higher in intervention group (88; 95% CI 82-94) vs. historic control (80; 95% CI 74-86; P=0.039) Learner Reaction: Using 5-point Likert scales with a higher score indicating higher opinion (mean±SD), level of satisfaction with review sessions higher among intervention group (4.04±0.82) vs. historic controls (2.93±0.59; p=0.039)	Use of historic controls and it was unclear if both groups completed the same exam questions
Hettinger et al. 2014 ¹⁸	Psychiatry Residents (22)	Impact of clickers used during a supervised 5-session (90 mins each) interactive review of Psychiatry Residency In-Training Exam (PRITE) questions from previous years' exams on performance in PRITE exam, compared with historic controls that completed the PRITE exam prior to the intervention and had prepared for the exam by unsupervised, independent study.	Learning Outcomes: Improvement in PRITE exam performance higher in intervention group (increase of 17.0±16.6: baseline score 152) vs. historic controls (increase of 6.4±12.6: baseline score 158; P=0.0068)	Use of historic controls and method of study for the exam also differed between the groups, independent of the use of clickers

Table 2: Summary of Non-Controlled Studies Evaluating the Use of Clickers Amongst Practising Healthcare Professionals

Citation	Participants (N)	Study Evaluation	Summary of Results	Limitations ^a
Cross Sectional Survey				
Kung et al. 2012 ²¹	Radiology residents (38) & physicians (57)	Impact of use of clickers in resident education sessions on learner and speaker satisfaction	<p>Learner Reaction: Using 5-point Likert scales with a higher score indicating higher opinion (mean, 95%CI) residents indicated that they learn better from a presentation that incorporated the use of clickers than from one that did not (4.0, 95%CI 3.7-4.3), were more likely to attend a lecture that incorporate the technology (3.70, 95%CI 3.4-4.0), feel more comfortable answering questions in anonymity (4.5, 95%CI 4.3-4.8), and appreciated comparing their answer to that of their peers (4.0, 95%CI 3.8-4.2).</p> <p>Speaker Reaction: Using the same scale, speakers felt they were not adequately trained in how to use the clickers (3.5, 95%CI 3.12-3.88), and they were neutral as to whether it was too time consuming to incorporate clicker questions into their presentations (2.9, 95%CI 2.5-3.21). In contrast, speakers felt that participants were more engaged (4.3, 95%CI 3.9-4.8), and that it helped them better gauge resident understanding of the material (3.7, 95% CI 3.0-4.4).</p>	60% response rate
Observational Case Series				
Hajjar et al. 2003 ²⁶	Various healthcare professionals (27)	Impact of use of clickers during structured interactive teaching sessions on knowledge gained during presentation	Learning Outcomes: Paired comparison of pre- and post-education knowledge test scores demonstrated overall increase by a median of 16% (p=0.002)	Unclear if pre- and post-presentation questions were the same
Turpin 2003 ²²	Orthodontists (600)	Impact of use of clickers during conference presentations on learner satisfaction	Learner Reaction: Using 5-point Likert scales with a higher score indicating higher opinion (mean), participants felt that clickers significantly increased their involvement in the presentations (3.97), should continue to be used in future meetings (4.06), increased the level of their “take-home” information (3.18) and were worth the additional cost associated with their use at the meeting (3.79).	Response rate not reported
Homme et al. 2004 ²	Paediatric residents (not stated)	Impact of incorporating clickers into weekly education sessions on attendance	Learner Reaction: Sustained increase in attendance of 50% over the previous 2 years since the introduction of clickers into weekly education sessions.	Unclear if sustained increase relates to same residents or new residents
Latessa et al. 2005 ¹⁹	Various healthcare professionals (46)	Impact of incorporating clickers as part of a single presentation, which included the same	Learner Reaction: When asked to evaluate the effectiveness of the clickers (using 4-point Likert scale from “A lot” to “None), the majority of participants	

		MCQs answered pre- and post-presentation.	felt that the clickers made them more attentive (“A Lot”=67%; “Somewhat”=33%), allowed them to learn more than in traditional lecture formats (“A Lot”=22%; “Somewhat”=63%), made the lecture more fun (“A Lot”=84%; “Somewhat”=16%), and that they were more likely to consider using the clickers in their own presentations (“A Lot”=44%; “Somewhat”=33%).	
Trapskin et al. 2005 ²⁷	Internal medicine residents (15) & pharmacists (24)	Impact of clickers used to answer MCQs before and after a presentation (with review and discussion of post-education responses) on new anticoagulation guidelines on adherence to prescribing guidelines compared to a target threshold	Behaviour: Following the presentation, an audit of prescriber adherence to the new anticoagulation guidelines indicated adherence in 22 of 43 (51%) cases (lower than the target threshold of 75%).	No baseline data collected in relation to prescribing adherence
McRae et al. 2010 ²³	Nurses (153)	Impact of use of clickers as part of hospital based continuing education on learner and speaker satisfaction	Learner Reaction: The majority of participants either strongly agreed or agreed that clickers were easy to use (93%), helped their learning (95%), and that they would recommend the use of clickers as part of future presentations (93%). Speaker Reaction: Speakers indicated that clickers engaged the audience (100%), were useful in assessing audience comprehension (80%), and were helpful in assisting learners to apply knowledge from a presentation to case studies or critical thinking exercises.	
Ramoska et al. 2011 ¹⁷	Emergency medicine residents (not stated)	Impact of use of clickers as part of resident education sessions to respond to questions during presentations on learner satisfaction	Learner Reaction: All participants found the clickers easy to use (100%), with nearly all (94%) preferring to answer questions using the clickers rather than being called on or speaking out in a traditional manner, and the majority (68%) felt that the use of clickers kept them more attentive during the sessions.	Response rate not reported
Kadir et al. 2013 ²⁴	Dentists (157)	Impact of use of clickers in delivery of a one-day four-module workshop on smoking cessation on learner satisfaction	Learner Reaction: Of the 144 participants who attended the workshop until completion the majority stated that the use of clickers was enjoyable (94%), motivated them to stay until the end (92%), increased their curiosity (97%), and made them feel comfortable in answering questions in anonymity (100%).	Only those who attended the entire workshop completed the questionnaire
Grzeskowiak et al. 2014 ²⁵	Pharmacists (60)	Impact of use of clickers during conference presentations on learner satisfaction	Learner Reaction: Using 5-point Likert scales (from strongly agree to strongly disagree), participants strongly agreed or agreed that clickers were easy to use (94%), enhanced interaction (98%), allowed comparison of knowledge with that of their peers (78%), brought to attention their knowledge deficits (64%) and should be used again (94%).	Response rate not reported
^a Absence of a suitable control represents a limitation for each of these studies				

Lessons for Practice

- There is strong evidence that the use of clickers, or audience response systems, results in improved interactivity, learning motivation, cognitive involvement, attendance, and enjoyment, whereas effects on knowledge and practice driven outcomes remain unclear.
- While clickers may play an important role in enhancing education programs for practising healthcare professionals through resultant improvements in learning environment and learner satisfaction, absence of evidence in relation to improvements in knowledge and practice driven outcomes diminishes their routine acceptance and implementation into practice.

Figure 1. Flow diagram of included studies

