DOI of final article - https://doi.org/10.1016/j.compedu.2020.103896

A systematic review of audience response systems for teaching and learning in higher education: The student experience

Abstract
Eight databases were used to locate research articles examining the use of audience response systems (ARS) for large group teaching in higher education settings which focussed upon the student experience. Qualitative and mixed methods articles were screened according to selection criteria. Of the twenty selected studies, an analysis of the papers helped identify six interconnected themes: 1) engagement 2) interaction 3) anonymity 4) questioning 5) instant feedback and 6) technological benefits and limitations. The themes reveal the complexity of student learning experiences using ARS which, when presented as a model, contributes to current understanding and offers a framework of pedagogical conditions to consider when designing and implementing learning experiences when using ARS.

Keywords: Audience response systems, large group lectures, higher education, technology enhanced learning, pedagogy, active learning, systematic review.

1. Introduction

The rapid pace of change in scientific and technological innovation gives rise to the argument for greater emphasis on preparing learners to be intellectually capable of being adaptable; developing their skills, knowledge and understanding in order to respond to the demands brought about by continuous change largely due to advancements in digital technologies. As life-long learners, students will need to possess 'new skills, new knowledge and new ways of learning' in order to survive, contribute and prosper in a digital age (Kuhlthau, Maniotes & Caspari 2015). For a generation growing up in the midst of technological developments, they arrive in higher education with existing expertise in using a range of technologies. Referred to in various terms such as 'digital natives' (Prensky 2001), 'millennials', (Howe & Strauss, 2000), or the 'net generation' (Oblinger 2003), it has been argued that Students of the 21st Century are immersed in interactivity, multimedia and social networking as part of their everyday experience. The 'traditional' approach to teaching and learning in higher education involves a lecture-style format involving large groups of students sitting in rows with limited opportunity for interaction either with their peers or with the teacher. This transmission-based, passive experience (Laxman 2011) is viewed as failing to meet the needs of the learner.

In their classic study, Ruhl *et al.* (1987) compared student knowledge retention using an active-learning approach with a traditional lecture approach and found both short-term and long-term retention of the lecture material was better for students engaged in active learning. In a 45-minute lecture, they found that inserting a two-minute break every fifteen minutes where they worked in pairs to compare and clarify their lecture notes helped students retain more course content. For active learning processes to occur in the classroom, Gleason *et al.* (2011) emphasise the importance of teachers changing their concept of learning from simple knowledge acquisition to a more consequential knowledge construction with application of skills thereby shifting some control of the learning environment from the teacher to the learner. It requires active student participation in environments which have been carefully structured by teachers to facilitate student engagement, enhance relevance and improve recall. While there are numerous methods of implementing an active learning approach such as Mazur's Peer Interaction active learning strategy (Crouch and Mazur 2001), they all share one important aspect: the learner must be actively engaged in the classroom learning and teaching processes. One such process is the use of questioning.

1.1 Audience Response Systems

Where large groups of students are taught together in, for example, a lecture theatre, questions asked by the teacher may be directed at the group in general with selected students volunteering a response. Variations in organisation might involve opportunity for discussion in pairs or groups so that they could explore, explain and challenge each other's thoughts and ideas and consider the most reasonable answer to a given problem. What is more difficult is the ability to allow all students to indicate their individual answers and for the teacher to be able to collect these and present collated responses to the whole group for further discussion. The introduction of handheld devices into the lecture theatre or classroom setting provide a means of allowing all students an opportunity to transmit their individual responses to questions presented and are referred to by a range of terms: clickers (Lantz & Stawiski 2014; Velasco & Cavdar 2013), classroom communication systems (White, Syncox & Alters 2011), audience response systems (Connor 2011; Cain & Robinson 2008), voting systems (King 2016; Mathiasen 2015) and student response systems (Klein & Kientz 2013). Questions may be presented at any point during the session and students may respond individually, in pairs or as part of a group. Responses can be collated and shared with the students as graphs during the session or viewed only by the teacher during or after the session. Results can be anonymised so that other students and even the teacher are unable to identify an individual's answers.

Although low-tech devices such as a simple show of hands, coloured cards or paddles may be employed, arguably, the increasing speeds of connectivity and data transfer provide greater opportunities for interaction within the teaching and learning space. Widespread connectivity via WiFi, Bluetooth and infrared allow the use of mobile devices such as tablets, laptops and mobile phones.

2. Literature review

Systematic reviews examining research literature on the use of audience response systems (ARS) in higher education and published in the past eight years, have examined various effects such as educational outcomes (Grzeskowiak *et al.* 2015); learning outcomes (Chien, Chang & Chang, 2016; Atlantis & Cheema 2015; Nelson *et al.* 2012); cognitive outcomes (Hunsu *et al.* 2016); exam results and student achievement (Castillo-Manzano *et al*. 2016, Hussain & Wilby 2019) and the acceptance and use of clickers (Rana, Dwivedi & Al-Khowaiter 2016). The populations examined in these studies vary with Atlantis & Cheema, (2015), Grzeskowiak *et al.* (2015) and Nelson *et al*, (2012) limiting their enquiries to health students or professionals as well as pharmacy education (Hussain & Wilby 2019). Rana *et al* (2016) examine the use of clickers within business and management programmes and Castillo-Mazano *et al.* (2016) examine ARS in both university and non-university settings.

Chien *et al*'s (2016) review of research which examined literature published up to and including 2013, report strong evidence of the superior effect of ARS compared to traditional lectures and the positive effects of ARS interventions on knowledge gain. Similarly Hussain and Wilby's (2019) review of papers up to 2018 find a positive impact of using ARS in the classroom and as a tool to enhance active learning. Despite this, there appears to be limited knowledge and understanding regarding the role of ARS in student acquisition of concepts (Kay and LeSage 2009a) which might shed light on the process of learning; an issue also highlighted by Hunsu *et al* (2016) who suggest limited availability of frameworks to link learning gain with existing theories of learning. Kay & Lesage recommend that further research be undertaken in order to examine what is engaging about ARS and to explore whether interaction is 'superficial or meaningful' in regard to learning (2009a p. 826). Fies & Marshall highlight the need to explore 'diverse pedagogical approaches' with particular attention towards group-based methodologies, anonymity and the use of the ARS for scaffolding learning through formative assessment (2006 p. 106).

3. Aim and objectives of this systematic review

This paper addresses the apparent paucity of systematic reviews incorporating evidence from qualitative and mixed-methods studies. In examining existing systematic reviews of the literature, it appears that reviews of qualitative evidence and mixed method studies is limited. This, perhaps, is not surprising as the technology used lends itself to collection of quantitative data as it involves testing user satisfaction scores with a large sample of participants; although insight is superficial, data is statistically valid and can be generalised. Liu et al, (2020) describe qualitative studies as being over-reliant on self-report data with the lack of objective quantitative data leading to less robust research data, but we contend that quantitative data lacks detail and rich description which can be found in qualitative studies. The existing body of quantitative work focusses mainly on learning outcomes and student performance rather than engaging with the depth and complexity of student learning experience in order to explain why and how ARS engages students in learning. This is not a criticism of quantitative methods of data collection and analysis but merely an observation that both approaches offer different ways of understanding a specific phenomenon.

Specifically, as a systematic review, evidence drawn from empirical studies will be appraised and synthesised to present 'informative and evidence-based answers' to specific questions (Dickson *et al*, 2014 p.3). This process is undertaken in seven main stages, as outlined by Gough, Oliver & Thomas (2012 p.8), beginning with the initiation of the review to finally communicating its findings with the intervening stages involving the formulation of the research objectives; designing a search strategy; describing the characteristics of the studies; quality appraisal and synthesis.

The main aim of this review is to contribute to the pedagogical discussion surrounding the use of ARS. It will focus upon research which examines how ARS is experienced by students in large group sessions in higher education settings and the way it impacts on their learning.

The objectives of this systematic review can therefore be summarised as follows:

1. To synthesise and critically analyse qualitative and mixed method research which examines how students experience the use ARS as part of a large group in higher education settings.
2. To examine how ARS technologies support learning from the perspective of the students.
3. To propose a hypothetical model representing the student experience of using ARS on their learning.

4. Methodology

In order to locate relevant papers which focus upon the use of ARS technology for teaching and learning in higher education and which draw from a broad disciplinary context, a systematic search was conducted on the following electronic databases: British Educational Index (BEI); Education Research Complete (ERC); Education Resource Information Centre

(ERIC), The Cumulative Index to Nursing and Allied Health Literature (CINAHL); Web of Science; Psychinfo; Medline and Research into Higher Education. Where available, filters were applied to focus upon peer-reviewed articles written in English and publications were limited to the time period January 2006- February 2020. Limiting the search to publications which had been subject to a process of examination through peer review provided a layer of quality assurance as part of the design of the systematic review.

The articles included in this review provide an insight into student experiences of using ARS technologies in higher education settings and the findings of this study might be examined in light of other systematic reviews focussing upon literature which has not been subject to peer review. After completing the screening of full papers, hand-searching and reference checking was also employed. Journals which yielded the most results were selected for reference checking alongside any relevant systematic reviews or meta-ethnographic studies. Finally, Google Scholar was used to locate any articles which had not been retrieved by the processes described above.

The search criteria were designed to locate any articles which focussed upon the use of ARS for large group teaching and learning. The following keywords allowed for variation in terminology for ARS in journal articles; clickers OR audience response system* OR class response system* OR student response system* OR immediate response system* OR voting system* OR electronic feedback system* OR class communication system*. To retrieve articles which examined the use of ARS for teaching and learning, the search included the following terms; teach* OR learn* OR education* in addition to cohort OR class OR large group OR lecture. The search terms were deliberately designed to be quite broad in order to allow as many studies as possible to be retrieved.

4.1 Inclusion and exclusion criteria

A summary of the inclusion and exclusion criteria are presented in table 1. Papers were included if they undertook empirical research which sought to examine the experiences of the students when using ARS during large group face-to-face teaching and learning sessions. Small-scale, situated research studies oriented towards understanding perceptions, attitudes and feelings of those concerned have been included as opposed to larger scale studies which seek to identify what may be causal, generalisable and quantifiable. Research designs which may be described as naturalistic or ethnographically-oriented (Cohen, Manion & Morrison 2011) where the research design would allow in-depth examination of student experiences of using ARS would be relevant. Papers found to be non-empirical, descriptive or purely theoretical in content were excluded alongside editorials.

As this systematic review focuses on the higher education context involving students undertaking either undergraduate or postgraduate studies, papers where participants are located in other educational settings for example, nursery, primary, secondary or further education are excluded. Furthermore, papers are also limited to those which examine the use of ARS in large group settings. What constitutes a 'large group' in terms of number of students may be subject to various interpretations and for the purposes of this review, the authors decided a class size of more than 30 students constitutes a large class – corresponding to the Higher Education Academy and the authors' own institutional definitions. Further to this, data collection in qualitative research design might involve a limited number of participants, however, there is a distinction to be made here between the number of students in the taught session and the number of participants involved in the data collection process and it is the former which is used as part of the inclusion criteria.

Studies which involved distance, on-line or off-campus learning opportunities such as teaching practice, clinical placement or field work, for example, as part of a science programme of study, were excluded with the focus being placed upon a physical classroom or lecture theatre on-campus, real-time face-to-face teaching and learning experience. There were no exclusion criteria with regard to disciplines, geographical location or subject-related content, however, papers which examined the use of ARS as part of academic support sessions, for example, generic workshops on academic language, were excluded as these were not located within a specific programme or discipline. Where the intervention was concerned, papers which examined the use of ARS, including text-based or web-based response systems employing students' own technology, such as their mobile phone, to support, enable or enhance teaching and learning were included. As indicated earlier, the population was limited to a large group (30+) of undergraduate or postgraduate students in a face-to-face setting as part of a taught programme within higher education. Beyond this, there were no restrictions placed upon the way in which the technology was used, for example, students might respond individually, in pairs or as part of a smaller group and at any point in the taught session.

Inclusion Criteria	Exclusion Criteria
• Empirical research • Use of audience response systems (ARS) • Large groups (30+) involved in the taught session • Real-time, face-to-face teaching • Higher Education settings • Studies focussing upon understanding the student experience (e.g. attitudes, experiences, feelings) • Peer-reviewed journals • Qualitative or mixed methods research • All fields/disciplines • Written in English • Published between January 2006-December 2018)	• Editorials • Non-empirical • Focused on teacher experience • Purely theoretical • Literature reviews • Settings which are not Higher Education e.g. secondary, primary, further education • Quantitative research (including survey methodology) • Online, distance or off-campus learning • Academic support sessions

Table 1. *A summary of the inclusion and exclusion criteria*

4.2 The screening process

Undertaken in four stages, the systematic review screening process adhered to the recommendations from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) see figure 1. This approach involved the following stages; 1) the removal of duplicates by author, title and date using Refworks and Excel; 2) the removal of papers which, according to the abstract, did not have a relevant perspective or focus. Reviewers undertook this task on an individual basis and then worked in pairs on the same list to compare and agree decisions to include or exclude; 3) examination of full texts with reviewers again comparing the same list and agreeing the outcome. For this stage, articles were examined to determine the population, intervention, comparison (if any) the outcome of the intervention and context for each paper all of which were tabulated (Brunton, Stansfield, & Thomas 2017). This allowed reviewers to adhere to and compare one another's evaluations according to the selection criteria; and finally, 4) analysis of each paper to review, identify and categorise each article's content and contribution. Throughout this process, reviewers met at appropriate intervals to ensure consistency of approach.

4.3 Quality of the studies

The authors of this paper view appraisal of quality and relevance of qualitative research to be distinct from the appraisal of quantitative data. Once the studies for the quality assessment stage were identified, the authors individually mapped the characteristics of each of the included papers using a criteria checklist adapted from two frameworks for qualitative reviews (Walsh & Downe 2005 and CASP 2013). Where quantitative data was integrated into the study design, a criteria checklist adapted from Bryman, Becker & Sempik (2008) was used. There was a conscious decision that the criteria should not be overly prescriptive but instead allow for informed judgements rather than a rigid ticking of boxes. While a combination of factors contributed to the choice of selecting a paper, some of the persistent factors evident in the papers which were excluded involved a lack of reporting exact sample sizes, ages and stages of students involved, subject(s) in which ARS is used and specific detail about the ARS technology used. Research described as 'mixed methods' was variable in quality with, for example, quantitative surveys incorporating one open question which yielded limited qualitative data and provided minimal insight into the experiences of the students. The authors found that studies from 2018 onwards were of better quality with more rigorous reporting of sample populations and qualitative / mixed methods approaches.

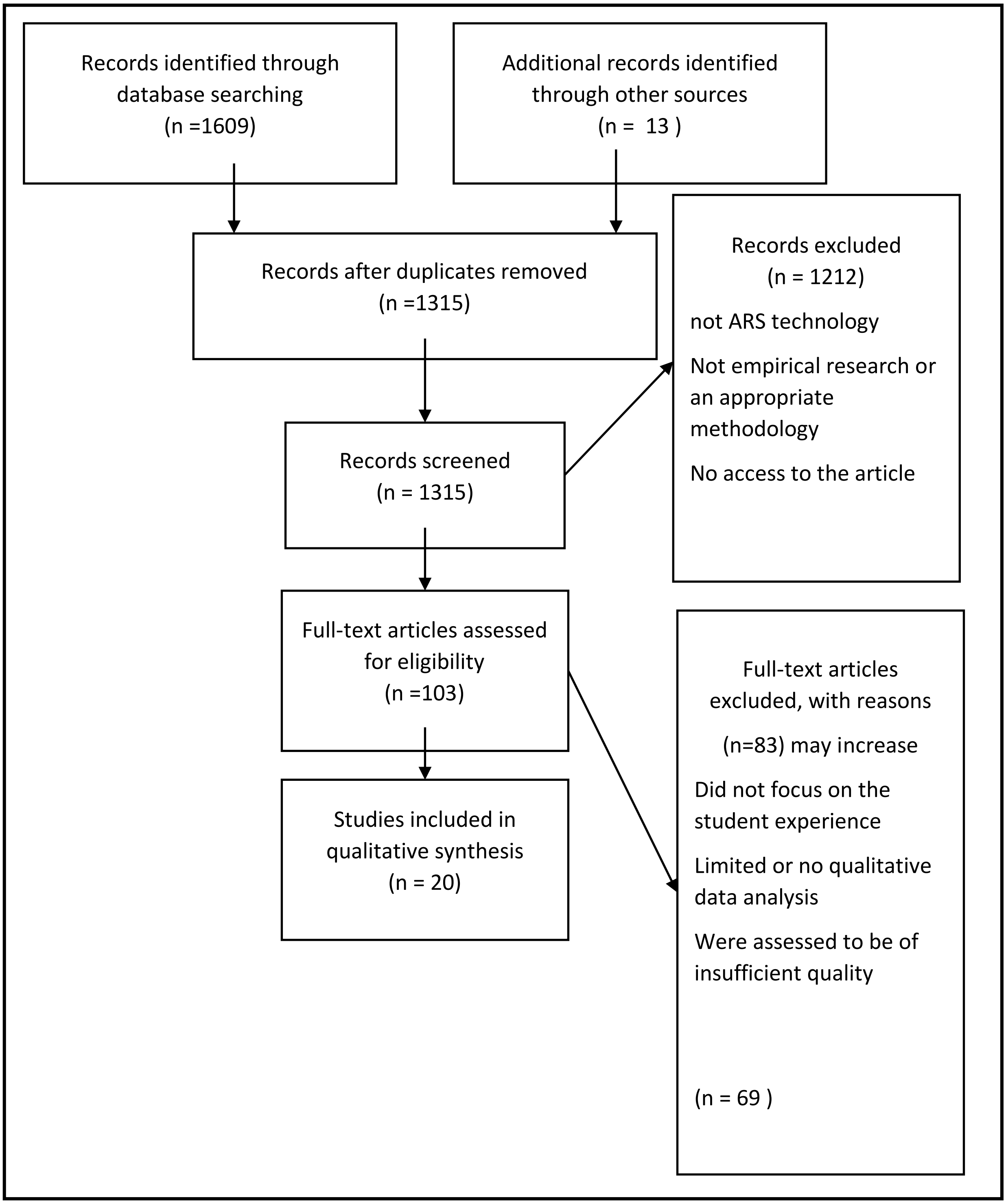

Figure 1 *PRISMA flow chart of events (Liberati, Altman, Tetzlaff, Mulrow, Gøtzsche, Ioannidis, Moher and the PRISMA Group, 2009).*

4.4 Data abstraction and analysis

In the first instance, the final papers were examined to identify publication dates and the range of countries, disciplines, and types of technology used within the studies with data collated and presented in table 2. Also summarised are the number of students involved in each of the interventions and the time over which the research was conducted. Thereafter, data were abstracted from the studies with the authors working independently to identify potential themes from the reported findings of each study. On completion, the two authors reviewed each other's work to discuss and agree the main themes associated with student experience of ARS (see table 3).

	Author(s)	Date	Journal	Discipline	Student status	Type of technology	Group size	Country	Length of Time of ARS intervention
1	Brady, M., Seli, H. & Rosenthal, J.	2013	*Educational Technology Research & Development*	Educational Psychology	UG, first year	TurningPoint 2008 software with ResponseCard IR.	Fall cohort 87 students in Clicker group 78 in 'traditional' group using paddles to respond	USA	Five lectures
2	Egelandsdal, K., & Krumsvik, R.J.	2017	*Education and Information Technologies*	Psychology (Qualitative methods)	UG first year	Not specified	173	Norway	Five, two-hour lectures
3	Florenthal, B.	2019	*Journal of Marketing Education*	Marketing	Not specified	Socrative	40	USA	One semester
4	Gauci, S. A., Dantas, A. M., Williams, D. A. and Kemm, R. E.	2009	*Advances in Physiology Education*	Physiology	UG second year	Interwrite PRS 9	132	Australia	Three 50-min lectures/wk for 12 wks
5	Grund, C. K., & Tulis, M.	2019	*Educational Technology Research and Development*	Information studies for Business and IS Engineering	UG first year	Not specified- students used their own devices	93 (control group 134)	Germany	One semester
6	Heaslip, G., Donovan, P., & Cullen, J. G.	2014	*Active Learning in Higher Education*	Business -Operations and Supply Chain Management module	UG final year	i>clicker classroom response system by i>clicker	132	Ireland	16 week semester-long module
7	Hoekstra, A	2008	*Learning, Media and Technology*	General chemistry course Main discipline not given	UG first or second year students	Hyper-Interactive Teaching Technology	Not specified. Attracts 800 in the fall and 300 in the spring	USA	Over 3 years
8	Hoekstra, A	2015	*Teaching Sociology*	Sociology of gender AND Drug use in society	Freshmen or sophomores	Not specified	1) 100 students 2) 35-50 students	USA	1) Over 4 semesters 2) Five instances between 2008-2013
9	Ismaile, S., & Alhosban, F.	2018	*International Journal of Advanced and Applied Sciences*	Nursing- Therapeutic communication course	UG Second year	Learning Catalytics (LC; Pearson UK, London, UK),	120	Saudi Arabia and UAE	14 lectures between September and December 2017

10	Jones, A.	2019	*The Journal of Asia TEFL*	English conversation (38 English majors and 3 Business majors)	Year three/four undergraduates	Poll Everywhere	41	South Korea	Two semesters
11	King, S, O., & Robinson, C. L.	2009	*Computers & Education*	Automotive, Aeronautical and Mechanical Engineering Mathematics focussed	UG second year students	Turning point	250 (145 Engineering students)	UK	Not specified
12	King, S.O.	2016	*Problems of Education in the 21st Century*	Automotive, Aeronautical and Mechanical Engineering	UG second year	Not specified	150	UK	Not specified
13	Masikunis, G., Panayiotidis, A., & Burke, L.	2007	*ALT-J Association for Learning Technology Journal*	Marketing and Business	UG first year	PowerPoint Vote System	240	UK	Not specified-
14	Masikunis, G., Panayiotidis, A., & Burke, L.	2009	*Innovations in Education and Teaching International*	Marketing and business	UG year one	Not specified	500	UK	Not specified
15	Mathiasen, H	2015	*Journal of Interactive Media in Education*	Physics	UG -two Universities	Not specified	1) 43 2) 20	Denmark	Not specified
16	Abdul - Meguid, E A & Collins, M	2017	*Advances in medical education and practice*	Dentistry	Not clear – presumed undergraduate	Poll Everywhere ARS	30 students	UK, Northern Ireland	Two lectures during the sixth and tenth week
17	Nielsen, K. L., Hansen G., & Stav, J.B.	2013	*Research in Learning Technology*	Engineering 2009) Physics 2010) physics 2010-11) physics, mathematics and social science 2011-12) maths, physics, social science, English and Norwegian	Preparatory classes for UG study	Not specified	50-70 per class, four classes	Norway	2009) 1 class, 4 weeks 2010) 4 classes, 8 weeks 2010-11) 2 classes whole semester 2011-12) 4 classes, whole semester
18	Patterson, B., Kilpatrick, J., & Woebkenberg, E.	2010	*Nurse Education Today*	Nursing - Adult medical surgical course	UG	Turning Point	38 using clickers 32 no clickers	USA	Six class days

19	Sheng, R., Goldie, C.L., Pulling, C. and Luctkar-Flude, M	2019	*Nurse Education Today*	Nursing science	UG	Top Hat	four-year (n=160) with second (n=45), third (n=58), and fourth (n=57) year and a two-year (n=75) accelerated program with first (n=36) and second (n=39) year students	Canada	12 week period
20	Van Daele, T., Frijns, C.,& Lievens, J.	2017	*British Journal of Educational Technology*	Applied Psychology-personality psychology (PP) or health psychology (HP).	UG	Mentimeter	185 in total for both PP and HP	Belgium	Nine lectures

Table 2. *An overview of the journal articles included in the final analysis*

5. Results

From January 2006 to February 2020, the publication of articles focussing upon students' individual experiences of using ARS appears to have occurred at a relatively steady rate. Included in the final list are journal articles from research carried out in Australia, North America, Europe, the Middle East and Asia revealing a world-wide interest in the use of this technology.
Where disciplines are concerned, studies in science, including medicine, nursing and dentistry, are slightly more evident than disciplines such as business and psychology and there was a dearth of research in arts disciplines. Finally, it was clear that earlier research involved the use of purpose made handsets whereas more recent articles tend to report on research using freely available software with students' own smart devices.

5.1 Student experiences of using ARS

Focusing on six overarching themes emerging from the twenty articles (see Table 3) which connect and overlap with one another, this section provides a synthesis of the findings from these studies.

Author(s)	Engagement	Interaction	Anonymity	Feedback	Questioning & Discussion	Technological benefits /drawbacks
Abdel Meguid & Collins 2017	x	x	x			x
Brady, Seli & Rosenthal 2013					x	
Egelansdal & Krumsvik 2017				x		
Florenthal 2019	x	x	x	x	x	x
Gauci et al 2009	x				x	x
Grund & Tulis 2019	x					x
Heaslip et al 2014	x	x	x	x	x	
Hoekstra 2008	x				x	
Hoekstra 2015	x	x			x	
Ismaile & Alhosban 2018			x	x	x	
Jones 2019	x		x			
King & Robinson 2009	x	x			x	x
King 2016	x	x	x			x
Masikunis, et al 2007	x				x	
Masikunis, et al 2009	x	x		x		
Mathiasen 2015		x			x	x
Nielsen, et al 2013						x
Patterson et al 2010	x	x	x		x	x
Sheng et al 2019				x		x
Van Daele et al 2017	x	x				

Table 3. *Main themes associated with student experience of ARS and their occurrence in the final reviewed studies*

5.1.1 Engagement

In terms of engagement, several articles note that students felt that using an ARS generated a sense of 'fun' (King and Robinson 2009; King 2016; Patterson, Kilpatrick & Woebkenberg, 2010; Mathiasen 2015; Van Daele, Frijns and Lievens 2017; Florenthal 2019) with Patterson, *et al*, 2010, (after Conelley *et al.* 2006) referring to ARS handsets as 'electronic entertainment toys'. The use of ARS can be perceived as being 'fun' resulting in a more positive response to instruction (King & Robinson, 2009). This, in turn, can also generate a more positive environment with students attending class, wanting to participate, and feeling they are more attentive in taught sessions (eg.,Hoekstra 2015, Florenthal 2019).

Masikunis, Panayiotidis & Burke, (2007; 2009) argue that student engagement arising from the use of ARS may be due to the effect of using something 'new' or the 'halo' effect created by teacher enthusiasm for the technology with the novelty of the approach being viewed as a means of relieving 'the boredom and monotony' of lectures' (King, 2016, p. 39) and increasing student interest (Jones 2019). Moving beyond the initial novelty, the sight of ARS handsets at the beginning of a lecture and the association of the handsets with questions to be asked in class can create a feeling of 'anticipation' or eagerness about the lecture (King 2016). With the use of the technology punctuating a lecture, students are also encouraged to re-focus their attention by making them 'think' (Gauci *et al.* 2009). Maintaining and stimulating attention is highlighted by Abdel Meguid & Collins, (2017) where the use of personal devices such as mobile phones to respond to questions were viewed by students as a means of repurposing these devices as enablers rather than as a potential source of distraction. Grund and Tulis (2019) describe how providing a chance to vote for favourite topics increases perceived influence and student autonomy leading to increased engagement.

Beyond gaining and maintaining student attention, cognitive engagement has been addressed by several studies. Brady *et al*'s (2013) qualitative study focussed specifically on the influence of polling systems on metacognition. In comparing students' perceptions of clickers in comparison to paddles when answering questions, they found higher levels of metacognition linked to the use of clickers. They argue that clickers should be used if learning goals require self-reflection, individual measures of learning or comparisons of polling questions free from judgement, as it is desirable to reduce the conformity effect. Masikunis *et al.* (2009) also suggest that small group work problem-solving activities in the lecture could promote the development of cognitive processes; however, the claim is not based upon specific evidence although Hoekstra (2015) argues that that clicker questions aid a metacognitive realisation by requiring students to examine how they thought about a topic before and how they think differently about things within the context of a lecture topic.

Several articles highlight the way in which ARS interventions make students think about what they have learned (Abdel Meguid & Collins 2017; Ismaile & Alhosban 2018; Van Daele, Frijns & Lievens 2017). Discussing and answering questions challenges students to become more aware of their learning process as they receive an increased level of formative feedback from the intervention (Egeslandal & Krumsvik 2017). The intervention provides students with more information about how well they have understood the subject matter by revealing misunderstandings to a greater extent than traditional lectures (Egeslandal & Krumsvik 2017). Seeing histograms of the collated responses helps students discern whether they understood the concept (Hoekstra 2008). By reflecting upon their response in relation to that of others offers the student prompts and anonymous feedback (Ismaile & Alhosban 2018) on their performance; this is viewed as an essential stimulus to learning (Heaslip, Donovan & Cullen 2014) because students may think they understand a concept but then perhaps realise they do not once they receive feedback.

King (2016) finds that the use of ARS questions helped students concentrate in class to keep them engaged and active. Students explain that the lecture feels more active not only because of the atmosphere of engagement but because they are using and reflecting upon their knowledge within the moment of a taught session instead of waiting for an exam to do so. Course material becomes meaningful because they are able to see how it might appear in actual problems (Hoekstra, 2008). Masikunis *et al.* (2009) contend ARS provides contrasting approaches to learning and teaching and therefore promotes deep active learning in students.

Both Patterson *et al.* (2010) and Nielson et al. (2012) emphasised the importance of the teacher in explaining and exploring the answers given by the students with Mathiasen (2015) and King (2016) highlighting the opportunity for the teacher to examine incorrect responses to questions. Nielson *et al* suggested that the possibility of including a 'don't know' answer might also allow students to signal any potential gap in their understanding rather than committing to a specific answer (2012). In all instances, the integration of the ARS engaged students in the process of learning by providing a means of communication between them and the teacher, offering opportunities for students to assess and reflect upon their understanding of the subject matter.

5.1.2 Interaction

Interaction is a problematic term and can be interpreted in a variety of ways. Teachers with large class sizes often cite greater interaction in their use of ARS (Abdel Meguid & Collins 2017; Ismaile & Alhosban 2018; King 2016; Masikunis *et al.* 2007; Patterson, Kilpatrick & Woebkenberg 2010). Although interaction between teacher and student occurs in traditional classrooms it is largely limited due to the logistics of engaging with students on an individual basis, consequently, interactions tend to be instructor-driven and/or instructor-initiated (King, 2016).

A far deeper interaction occurs in peer interactivity where students might discuss and compare their answers after voting or talk through a problem before voting (Gauci *et al.* 2009; King 2016). In such instances, interactivity is contingent upon group dynamics with students more likely to discuss answers if they know they will not be ridiculed or judged by their peers. This seems to be a particularly important element of the student experience and is discussed further with regard to anonymity in the following section.

Students perceive interactive lectures as contributing to their learning and they strongly identified active participation as a factor in improving learning (Masikunis *et al* 2009).The opportunities to discuss material help to generate activity that alleviates boredom or passivity usually present in the large lecture hall. They also value being active learners in small groups as it diminishes their experience of social alienation in a large lecture (Masikunis *et al* 2009).

Experiences may also be affected depending upon students' relationship to their peers (Egeslandal & Krumsvik, 2017; Ismaile & Alhosban, 2018). For example, Egeslandal & Krumsvik highlight the potential for superficiality, discomfort and lack of engagement in discussion should the students be unfamiliar with their peers, or if peers are unwilling to discuss or have no opinion to offer; in some instances when students are required to work in a group they may elect to work alone or feel they are unable to involve themselves in a group (2017). If the question is viewed as being relatively easy, some students will choose an answer on their own before turning to peers to compare their results (Heaslip, *et al.* 2014).

Masikunis *et al.* (2009) suggest that evidence for increased collaboration is found through small group work problem-solving activities in the lecture. Students place an importance on social constructivist approaches where learning is influenced by social interaction and collaborative learning. They use Renshaw's 1995 framework of learning and teaching approaches as an explanation of how the teacher guides students to adopt the language, practices, forms of representation and attitudes in social participation with others to help develop cognitive skills alongside content. They believe an interactive environment using ARS helps create a social constructivist environment where communication between students and teachers encourages collaborative learning. Here, students are able to reflect on their own understanding, articulate their responses to questions and engage in face-to-face explanation (Ismaile & Alhosban 2018). Hoekstra suggests the use of an ARS may have the effect of making the learning environment feel more cooperative as students help each other by evaluating each other's reasoning and 'catching each other's mistakes' (2008, p. 336). However, Hoekstra (2008) also finds that some students, (15-20% in her sample population), do not feel comfortable working cooperatively in lectures using ARS. She emphasises that in learning the new technology students experience some level of anxiety but over time they become comfortable with both clickers and cooperative interaction. It is also interesting to note some students preferred a more competitive yet supportive approach which was also viewed as being beneficial to learning (Heaslip *et al*. 2014) and contributing to a positive classroom atmosphere with students keen to compare their response to that of others (King 2016).

Some of the challenges of integrating peer discussion when using ARS were also revealed with Egeslandal & Krumsvik (2017) recognising that although the majority of the students experienced formative feedback from clicker interventions, slightly more than half of the group felt that peer discussions were useful in supporting this process. This, according to the students, was due to instances where there were no peers with whom they could discuss or the discussion itself was viewed as limited. Ismaile & Alhosban (2018) found similar patterns in their study of Arab nursing students where barriers to effective peer interactions are created due the students' lack of interest in answering questions, the students' lack of preparation prior to the session or insufficient knowledge on the topic.

In addition to social interaction, King also refers to 'technical interactivity' as the physical interaction between a student and their handset highlighting that the students get to 'do something' by selecting and pressing a button (2016, p. 34). This physical action effectively sparks student attention and maintains their engagement throughout a teaching session. Hoekstra emphasises that an ARS makes the learning environment feel more active because students hear and see more activity than they would during a traditional lecture (2008). The act of involving the students by asking them to respond to a question using ARS can potentially alleviate boredom (Hoekstra, 2008, King & Robinson, 2009, King, 2016) contributing to students' sense of involvement during a lecture (Florenthal 2019). Where students report that they feel more active during taught sessions they attribute this to being able to apply what they have learnt immediately using an ARS rather than during exams or other assessments (Hoekstra 2008). Although a small number of students in Masikunis at al's (2007) study raised concerns that the use of an ARS effectively reduced the amount of time available for learning within a session, this was contradicted by King's research which revealed that students felt that the use of the voting system did not impact negatively on lecture time (2016).

5.1.3 Anonymity

The anonymity provided by an ARS has been highlighted as beneficial by several studies (Abdel Meguid & Collins, 2017; Heaslip *et al*, 2014; Hoekstra, 2015; Ismaile & Alhosban, 2018; Patterson *et al*, 2010; Sheng et al 2019; Van Daele, Frijns & Lievens 2017; Florenthal 2019; Jones 2019). For example, Heaslip *et al*, (2014) find in their sample of 120 business undergraduates that the guarantee of anonymity increases student willingness to participate in the class. Students may worry about being the only one who does not understand a concept and the anonymity of the ARS helps alleviate that anxiety. Sheng *et al.* (2019) emphasise that students fear criticism and ridicule from peers and instructors by answering incorrectly or voicing an unpopular opinion. The role of the ARS in reducing anxiety and giving a voice to shy or less talkative students who can participate without becoming the focus of attention is highlighted by Hoekstra. 2015; Mathiasen, 2015; Nielsen *et al*

2013; Patterson *et al*, 2010; Florenthal 2019; Jones 2019. By using this technology, some students feel integrated in the learning community despite selecting responses which may not be correct or perhaps differ to the majority of the group (Hoekstra 2008). Where a student answers incorrectly and finds that there were others who had also selected an incorrect answer, this seems to give reassurance to the students concerned when they realise they are not the only ones giving what they may consider to be 'stupid' answers (King & Robinson 2009). Interestingly, this feature can also be a limitation, allowing, for example, some students to deliberately enter incorrect answers and skew the response results (Florenthal 2019).
When students use an ARS, there may be less of a conformation bias where students feel the need to agree to the norm rather than apply their own understanding to questions (Brady et al, 2013). Instead of feeling pressure to respond in the same way as the majority, students can answer 'honestly' and 'without shame' supporting the idea that an ARS supports discussions of greater variety and perspective than might be the case without the technology (Hoekstra 2015). Thus, cultivating a safe environment encourages passive students to become active learners and is one of the key advantages of ARS (Sheng *et al.* 2019). Reports of instant and anonymous formative feedback is the most prominent theme not only reported in Western institutions but also in studies of Arab classes (Ismaile & Alhosban 2018) where such feedback is rare. Prompt feedback not only allows students to confirm whether or not they have understood the concept but also acts as a catalyst for dialogue in an attempt to understand the correct response (King 2016; Nielsen *et al* 2013). The use of ARS helps students to be aware of their learning needs (Ismaile & Alhosban, 2018) and encourages them to study after the lectures (Gauci *et al.* 2009). This increased reflection upon their own understanding may contribute to better learning outcomes (Brady et al. 2013).

5.1.4 Questioning

Abdel Meguid & Collins, (2017) report that open-ended question types are best for class discussion and debate. If the ARS method does not involve active dialogue among students, then a push of the button may have replaced opportunities for thinking aloud and practicing verbal communication skills in the classroom (Patterson *et al.* 2010). Students appreciate questions that have several options that are correct or perhaps partially correct because this creates good opportunities for discussion making them feel more focused in terms of processing all the options and more aware of the nuances (Egeslandal & Krumsvik 2017). Similarly, Sheng *et al.* (2019) point out that students prefer questions that directly correspond to key concepts discussed, which assist in the prediction of future exam questions and topics. Students report that questions are particularly valuable if their opinions or answers are referred to and built upon in the continuation of the lecture (Van Daele *et al.* 2017) and that teachers adapt their explanations to the students' answers by exploring alternatives as well as discussing the correct answer (Egeslandal & Krumsvik 2017; Ismaile & Alhosban 2018). Thus, student motivation to respond to questions relies to some extent on the teacher's pedagogical skills. The length of time students have to vote also impacts on student perceptions of using ARS. Several studies point to negative perceptions in using ARS due to the time allowed to submit answers (Gauci *et al.* 2009, Mathiasen 2015; Nielsen *et al.* 2013; Florenthal 2019). If the time allowed to answer a question is too long, even a short amount of 'dead time' can have a negative impact, (Masikunis *et al*, 2007, p. 13). Yet, the time allowed for questions should be sufficient to enable students to reflect on answers without resorting to guesses or not participating at all (Mathiasen 2015).

In addition, questions have to be implemented as a natural part of the lecture and have a clear purpose because if they are not, students use a lot of time and energy trying to interpret the questions rather than working towards finding the solution. Sheng *et al.* (2019) note the importance of an organized question cycle – posing a question, allowing time to respond, displaying class answers and promoting discussion based on the results. Students reportedly preferred questions straight after a topic and think-pair-share questions (Gauci *et al*, 2009) where they can discuss and reflect on their answers. This places an emphasis on teachers' pedagogical skills with regard to the crafting of questions which may be more demanding than those found in traditional text books (Nielsen *et al.* 2013, p. 9).

5.1.5 Instant feedback and student learning

An ARS can be a barometer for personal understanding of the work (King & Robinson 2009) as students are able to see how course material might relate to relevant concepts assisting them in assessing their understanding (Hoekstra 2008). Instant feedback helps students to gauge their ability at a given point and reflect upon their learning with collated responses displayed to allow students to diagnose their level of understanding and performance relative to the class (Brady *et al*, 2013; King, 2016). Florenthal made a distinction between 'immediate' and 'delayed' feedback where the former offers instant gratification and encourages students to participate using the ARS and the latter, alongside open-ended questions, offers opportunity for critical thinking (2019 p.249).
Brady *et al.* (2013) find that when students use clickers as compared to paddles, they are engaged in the learning process in such a fashion that self-reflection and self-monitoring occurs. For learners who do not normally engage in questioning during a lecture the use of ARS helps guide them in the learning process in a metacognitive discovery of self-knowledge in the context of the lecture. In their study involving the use of clickers, Egeslandal & Krumsvik (2017) found that most students felt that the formative feedback from the interventions supported their ability to undertake self-monitoring. In particular, they experienced an increased awareness of their own understanding of the subject matter, a recognition of what was important for them to learn in the subject and what they should focus on further.

5.1.6 Technological benefits and limitations

Some of the technological benefits discussed within the studies have been explored in the sections above on engagement and interaction, most notably, the speed of processing responses from a large number of students and presenting these in a variety of formats to support discussion; here, we highlight some of the potential limitations of such technology. Firstly, several studies have referred to the reliability of the technology as being problematic (Gauci *et al.* 2009; Grund & Tulis (2019); King & Robinson 2009; Patterson *et al.* 2010) and the equipment being time-consuming to set up for use in class (King 2016; Patterson, *et al.* 2010; Nielsen *et al* 2013). Although these limitations do not seem to impact on students' perceptions of the usefulness of ARS, they nevertheless impact on the overall perception of ease of use.
Secondly, there is a large element of teacher competence and confidence in using this technology which impacts upon student experience of using an ARS. When students compared different teachers' approaches (Nielsen *et al.* 2013), they felt that not all instructors reflect in sufficient degree over their use of ARS in the classroom. If interactive moments are not integrated smoothly or naturally in the lecture, students appear to question the commitment of the teacher towards the technology (Nielsen *et al* 2013; Van Daele *et al* 2017). In some instances, student annoyance was

directed towards the design of the technology itself (Florenthal 2019), but in most cases, the students signalled that they would want teachers to have a clear goal of why they use ARS and to be consistent in their use of the technology. Infrequent use of ARS results in insufficient practice, lack of experience with the teacher potentially 'fumbling with the software' leading to a rather uneven experience for the students (Nielsen *et al.* 2013 p.5).

Finally, there is a distinction to be made between technologies which require purpose-made handsets and those which utilise the students' own hand-held devices. With the former, students would need to have access to handsets, perhaps by purchasing their own or if maintained as a set by the institution would need to be distributed at the start of a session and collected at the end. This would require some time to organise and complete during a session or would place a cost implication on either the students or the department. Utilising students' own technology such as mobile phones might be more cost effective but could still incur cost if text messages are involved and may exclude some students if their devices are not compatible with the system employed. However, Grund & Tulis (2019) point out many students have mobile devices and are keen to use them in the classroom. Additionally, many ARS have been improved over the years so conducting polls is uncomplicated and feasible to incorporate in large-scale lectures.

6. How ARS supports student learning: a proposed model

Interconnections between the concepts and themes are evident with a range of factors influencing or arising from the student experience; these are summarised in table 4. This paper presents a model for consideration which seeks to identify the various factors and the potential relationship between them. Organised as concentric circles, the innermost, central circle draws together factors which focus upon the affective domain; these are the ways in which students reflect upon, assess and become aware of their own learning and how they feel about the learning experience with regard to self-confidence and their sense of involvement.

The second circle focuses upon the learning environment and the way in which students are involved in the learning experience. For example, participation by responding to questions may also involve discussion with their peers perhaps requiring them to work collaboratively to solve specific problems or perhaps compete on individual basis or as part of a group. The use of the ARS allows the teacher to gather responses as soon as students have made their selection. The collated results may be shared with the students almost immediately should the teacher opt to do so. These factors contribute to the development of an active learning environment, enabling students to engage with the content of the session and interact with one another as opposed to being an audience receiving information.

The outer circle represents the ways in which the active learning environment is designed and may impact the actions and experiences of students. For example, anonymity is not a feature of an active learning environment but, according to the papers reviewed, it may act as a catalyst, increasing student confidence to participate and thereby enable more honest evaluation and reflection upon their learning. Question design is also a critical element with the type and frequency influencing the learning experience. Rather than punctuating the taught session with superficial questions, careful design offers opportunities to examine and discuss concepts and ideas without the sense that the pace of learning is compromised.

Themes/concepts	*Student experience of ARS*	*Relevant articles*	*Implications for teaching and learning using ARS*
Engagement	Fun	King & Robertson (2009); King (2016); Patterson, Kilpatrick & Woebkenberg (2010); Van Daele, Frijns & Lievens (2017); Florenthal (2019)	Encouraging participation
	Attention (gain, maintain and refocus)	Gauci et al. (2009); Hoekstra (2015); Abdel Meguid & Collins (2017), Florenthal (2019)	
	Novelty	Masikunis, Panayiotidis & Burke (2007; 2009); King, (2016); Florenthal (2019); Jones (2019)	
	Engaged in the learning process	Grund & Tulis (2019); Hoekstra (2008); Heaslip, Donovan & Cullen (2014); Abdel Meguid & Collins (2017); Van Daele, Frijns & Lievens (2017)	Self-assessment, reflection and feedback
	Cognitive engagement	Masikunis et al. (2009); Hoekstra (2015)	
Interaction	Peer interaction	Masikunis et al. (2009); Hoekstra (2008); Heaslip (2014); Eglandsdahl & Krumsvik (2017)	Collaboration, competition, discussion, organisation of the cohort (individual, group, paired)
	Teacher-student interaction	Abdel Meguid & Collins (2017); King (2016); Masikunis, Panayiotidis & Burke (2007); Patterson, Kilpatrick & Woebkenberg (2010)	Question design, responding to student answers
	Technological interaction	Masikunis, Panayiotidis & Burke, (2007); Hoekstra, (2008); King & Robiinson (2009); King (2016); Florenthal (2019)	Sense of involvement participation Pace of learning

Anonymity	Willingness to participate	Heaslip, Donovan & Cullen (2014); Sheng et al. (2019); Florenthal (2019); Jones (2019)	Participation
	Reduces anxiety/ sense of embarrassment	Patterson, Kilpatrick & Woebkenberg (2010); Hoekstra (2015); Mathiasen (2015); Nielsen, Hensen & Stav (2013); Florenthal (2019); Sheng et al. (2019);	Confidence
	Allows students to assess their own understanding	Masikunis et al. (2009); Nielsen, Hansen & Stav (2013); Hoekstra (2015); Mathiasen (2015); Ismaile & Alhosban (2018); Sheng et al. (2019): Florenthal (2019)	Reflection, self-assessment
Questioning & discussion	Design of questions-open/closed	Gauci et al (2009); Patterson, Kilpatrick & Woebkenberg (2010); Abdel, Meguid & Collins (2017); Egeslandal & Krumsvik (2017)	Discussion, integrated as opposed to 'add on'
	Formative assessment for teacher	Van Daele, Frijns & Lievens (2017) Egeslandal & Krumsvik (2017); Ismaile & Alhosban (2018)	Lecturer's response to students' answers
	Number of questions and time allowed for questions	Masikunas et al (2007); Gauci et al. (2009); Nielsen, Hansen & Stav (2013); Mathiasen (2015); Florenthal (2019)	Pace of learning
Instant feedback & student learning	Student awareness of their own understanding	Masikunis et al (2007); Hoekstra (2008); Masikunis et al. (2009); King & Robinson (2009); Brady, Seli & Rosenthal (2013); Abdel Meguid & Collins (2017); Sheng et al. (2019): Florenthal (2019)	Self-assessment, metacognition, self-directed learning
Technological benefits & limitations	Speed of processing	Brady, Seli & Rosenthal (2013); King (2016)	Pace of learning
	Time to set up, design and reliability of the technology	Gauci et al (2009); Grund & Tulis (2019); King & Robinson (2009); Patterson, Kilpatrick & Woebkenberg (2010); Nielsen, Hansen & Stav, (2013); Florenthal (2019)	Pace of learning
	Teacher confidence and competence Purposeful use of ARS	Nielsen, Hansen & Stav (2013); Van Daele, Frijns & Lievens (2017); Sheng et al. (2019)	Integrated as opposed to 'add-on'

Table 4: *Student experiences of using audience response systems: identifying themes and concepts*

Timing of questions may be considered in relation to the pace of learning where more complex problems require more time for the student consider and respond to while questions that are not as demanding require less time. Further consideration may be given to the number of questions integrated into the session; too many and the students' learning may be punctuated with a lot of pauses, too few or perhaps limited use of questions and students may view this as superficial to their learning. Technological problems may also cause students to question the relevance and usefulness of the ARS if this results in interruptions during the session.

The organisation of the cohort also contributes to the student experience. Students may respond on an individual basis, as part of a group or as a pair. Discussion prior to or after voting and the possibility of re-voting afterwards are all factors for consideration by the teacher. There may be a combination of approaches to provide variety with, for example, students selecting their response on an individual basis before undertaking group discussion with the opportunity to re-cast their vote afterwards. During this sequence of events, the teacher may choose to present the collated responses to inform discussion or retain this information until the end to show any shift in responses which might, in turn, prompt further discussion.

Drawing from the papers in this review, there is clear indication that the teacher needs to be responsive to the students. The ARS provides the teacher with a means to assess student learning during a session and this connects to the final factor in the outer circle, namely the teacher's response to student answers. Having the collated data from the cohort available quickly and efficiently, the teacher may be able to identify any misunderstandings and respond to these as they arise. Between sessions, the teacher can use this information to provide students with content which supports the ongoing process of learning and which feeds into the next session as preparatory material. Decisions would need to be made should there be a minority of students who appear to have misunderstood as the majority of students may find the pace of learning reduces if the teacher chooses to address this within the session. Here, if anonymity is confined to the students, the teacher may be able to identify individuals who are in need of specific support.

Thus, these three domains provide a framework towards an understanding of the way in which various factors impact upon the learning experience of students when an ARS is employed. Such a model may provide teachers with a set of pedagogical conditions to consider when designing the learning experience of students.

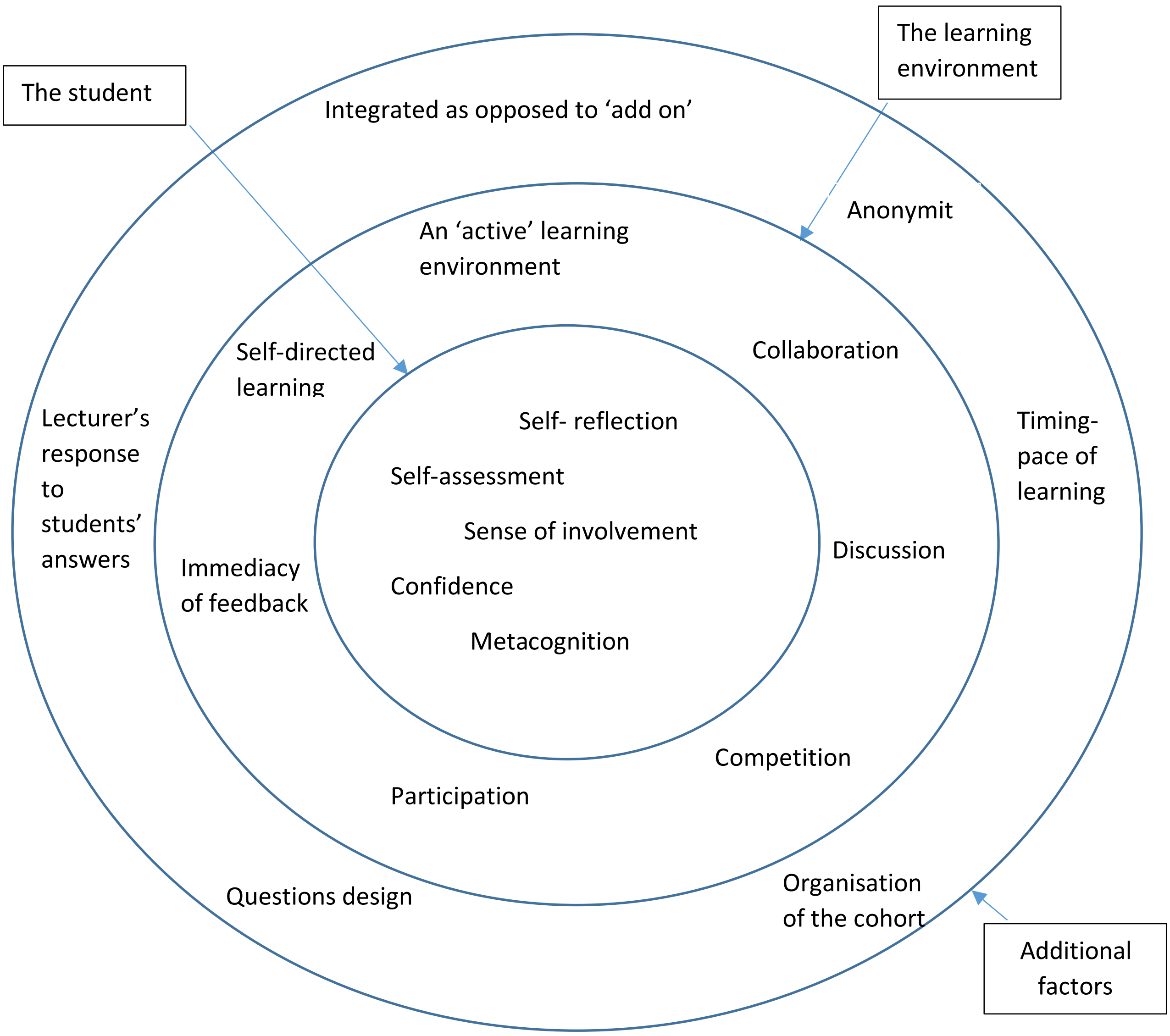

Figure 2. *How ARS supports student learning: a proposed model*

7. Conclusion

The main aim of this review is to further understanding of the pedagogical discussion surrounding the use of ARS; systematically reviewing, summarising and synthesising existing research in the field which focuses upon student experiences of ARS. Responding to questions raised by previous systematic reviews regarding pedagogical approaches (Fies & Marshall 2006) in addition to engagement and types of questions (Kay & LeSage 2009a 2009b), this paper establishes groundwork in offering a model which identifies the main factors which seem to be most influential in terms of student learning and the relationship which appears to exist between these factors.

The most widely discussed theme within and across the articles is the value of ARS with regard to student engagement. Studies highlighted the complexity associated with this concept which extended beyond measuring attendance, reading preparation prior to class, self-reported enjoyment or test scores (Patterson *et al.* 2010). The number of students answering a question may offer some indication of engagement (Abdel Meguid & Collins 2017), however, it is the manner in which students engage which provides a more detailed and informative account of this phenomena. The systematic review undertaken by Kay & LeSage in 2009(a) suggested that further research be undertaken to understand what was engaging about an ARS and 'the impact of specific types of questions on creating student-centred, knowledge-rich learning that builds classroom community' (p. 826). Although this research does not provide a comprehensive response, the nature of engagement and its relationship to other, integral factors of the learning experience have emerged. For example, the use of an ARS provides systematic and explicit opportunities for interaction between the teacher and the students and can act as a catalyst for peer discussion. The design for such interactions requires some consideration with the teacher making informed decisions based on their understanding of the group and the content of the session. Further detail regarding the time required for discussion, the sequence of events such as when votes are cast and when peer discussion takes place also need to be considered.

Question design is clearly a critical element and can allow exploration in the process of understanding or may rely on recall of existing knowledge. The number, type and time allowed for questions during the course of a taught session will also need careful consideration; for example, too many questions punctuating a session may slow the pace of learning as might lengthy deliberation over a single question. The research indicates that ARS use is not effective if used as a simple question and answer tool; an organized question cycle will help implement questions as a natural part of the lecture and involve opportunities for discussion before or after voting. If there is no opportunity to reflect on answers, the effectiveness of ARS is reduced. Furthermore, questions should directly relate to the key concepts covered in the lecture. In addition, Sheng *et al.* (2019) find students are dissatisfied when questions posed do not stimulate impactful discussions.

There is evidence that open-ended questions provide opportunity for deeper reflection. Where closed questions are used, the teacher's ability to explain alternative answers as well as the correct answer is crucial for student self-assessment and metacognition. These findings help allay fears that the use of an ARS in higher education marks a departure from academic teaching to 'edutainment' (Hoekstra 2008) although the suggestion that if students are having fun it means that learning is somehow diluted is somewhat problematic. Although enjoyment and interactivity do not determine learning, they are necessary conditions which predicate learning. A key feature of an ARS is the ability to gain instant feedback once voting has taken place. Prompt feedback allows students to confirm whether they have understood a topic or not and helps them to become aware of their learning needs. Instant feedback is not only useful for students but also enables teachers to make necessary pedagogical changes in order to address identified gaps in students' understanding. Masikunis *et al.* (2009) argue that the pedagogic role played by an ARS helps teachers develop their understanding and appreciation of constructivist learning and its impact on student learning. This may lead to better learning outcomes as positive or negative feedback helps self-reflection on learning (Hughes 2005). Thus, in the case of an ARS there is opportunity for increased self-reflection in both students and teachers. An ARS helps focus student attention and engages them in the learning process by providing feedback with opportunities to engage in self-reflection, all of which are necessary conditions for learning.

Responding to Fies & Marshall's review of 2006 which foregrounded anonymous participation as a critical feature there is further consideration given to anonymity as an important part of the learning experience. Diminishing anxiety and increasing students' willingness to participate offers greater opportunity for students to explore their own understanding and reflect upon their learning.

Students are free to provide input without fear of possible public humiliation or worrying about more vocal students dominating the discussion. However, as highlighted in the recent study undertaken by Florenthal (2019), there has been limited consideration given to the 'downside' of anonymity where some students may find it allows them to disengage and perhaps disrupt learning.

8. Implications for further research

Overall, the articles reviewed are limited from several contextual perspectives. Although the search protocol explored articles published worldwide, the majority of the studies involved research conducted in western institutes. Of the reviewed articles, six studies are from the UK, five are conducted in the US, one from Canada and five from Europe. There are a further three studies from Australia, South Korea and the UAE signalling a global interest. There is a preponderance of studies conducted in technical and science-oriented subjects – with engineering (2), physics (1), dentistry (1) physiology (1) and chemistry (1), in addition to nursing (3). Others included psychology (3), business /marketing (4) sociology (1) and English (1) with two studies involving a mixture of disciplines (2). The limited evidence base on ARS in sociological subjects might convey ARS is of less relevance in these subjects. In the examined database, there were no articles about using ARS in arts subjects. Students recruited in the samples vary along several individual variables but although survey data for these variables were gathered in some studies, they were seldom explored in a meaningful way. For example, reviewed studies provide little evidence of analysis as to whether there are gendered differences in preference for ARS (one exception being Hoekstra 2008) and this warrants further investigation. Similarly, subject suitability for ARS is not addressed by the studies reviewed and this is another aspect warranting further investigation.

9. Limitations of this study

The potential for bias is recognised as a common limitation of systematic reviews. After applying the selection criteria, a limited number of studies have been included and this forms the main limitation of this systematic review. Drawing from peer-reviewed journal articles may offer some assurance regarding the quality of the articles, however, this may also serve to exclude studies which have not been submitted to journals and yet contribute to the field.

Selecting studies which draw upon or include qualitative data may also be viewed as a limitation with a sense that the evidence is reported and subjective. However, the perspectives and experiences of students offer valuable insights into the way in which an ARS can influence and affect learning and we would argue that in combination with other studies using quantitative approaches, it is possible to gain a more detailed and holistic understanding. The conclusions are suitably tentative and would benefit from further contributions which test and revise the findings of these studies.

Conflicts of interest and funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors and there are no conflicts of interest.

References

Abdel Meguid, E. & Collins, M. (2017). Students' perceptions of lecturing approaches: traditional versus interactive teaching. *Advances in medical education and practice*, 8, 229–241.

Atlantis, E. and Cheema, B.S. (2015). Effect of audience response system technology on learning outcomes in health students and professionals: an updated systematic review, *International Journal of Evidence-Based Healthcare*, 13(1), 3-8.

Brady, M., Seli, H., & Rosenthal, J. (2013). Metacognition and the influence of polling systems: How do clickers compare with low technology systems. *Educational Technology Research and Development*, 61(6), 885-902.

Bryman, A., Becker, S. and Sempik, J. (2008). Quality criteria for quantitative, qualitative and mixed methods research: A view from social policy, *International Journal of Social Research Methodology*, 11(4), 261-276.

Cain, J. and Robinson, E. (2008). A primer on audience response systems: current applications and future considerations, *American Journal of Pharmaceutical Education*, 72(4), 77.

Castillo-Manzano, J. and Castro-Nuño, M. (2016). Measuring the effect of ARS on academic performance: A global meta-analysis, *Computers & Education*, 96, 109-121.

Chien, Y., Chang, Y. and Chang, C. (2016). Do we click in the right way? A meta-analytic review of clicker-integrated instruction, *Educational Research Review*, 17, 1-18.

Cohen, L., Manion, L. and Morrison, K. (2011). *Research Methods in Education*, Routledge: Abingdon

Connor, E. (2011). Using Cases and Clickers in Library Instruction: Designed for Science Undergraduates, *Science & Technology Libraries*, 30(3), 244-253.

Conoley, J., Moore, G., Croom, B., Flowers, J., (2006). A toy or a teaching tool? The use of audience–response systems in the classroom. *Techniques: Connecting Education and* Careers 81 (7), 46–48.

Critical Appraisal Skills Programme UK. (2013). *CASP checklists*. http://www.casp-uk.net/#!casp-tools-checklists/c18f8 accessed 17th September 2019

Crouch, C., & Mazur, E. (2001). Peer Instruction: Ten years of experience and results. *American Journal of Physics*, 69, 970-977.

Dickson, R., Cherry, G. M. and Boland, A. (2014). Carrying out a systematic review as a Master's thesis in A. Boland, M. G. Cherry and R. Dickson (Eds) *Doing a Systematic Review*, (pp. 1-16), London: Sage

Egelandsdal, K. and Krumsvik, R.J. (2017). Clickers and formative feedback at university lectures, *Education and Information Technologies*, 22(1), 55-74.

Fies, C. and Marshall, J. (2006). Classroom Response Systems: A Review of the Literature, *Journal of Science Education & Technology*, 15(1), 101-109.

Florenthal, B., (2019). Students' motivation to participate via mobile technology in the classroom: a uses and gratifications approach. *Journal of Marketing Education*, 41(3),.234-253.

Gauci, S.A., Dantas, A.M., Williams, D.A. and Kemm, R.E. (2009). Promoting student-centered active learning in lectures with a personal response system, *Advances in Physiology Education*, 33(1), 60-71.

Gleason, B. L., Peeters, M. J., Resman-Targoff, B. H., Karr, S., McBane, S., Kelley, K., & Denetclaw, T. H. (2011). An active-learning strategies primer for achieving ability-based educational outcomes. *American Journal of Pharmaceutical Education*, 75(9), 186.

Gough, D., Oliver, S. and Thomas, J. (2017). *An introduction to systematic reviews*. London: Sage.

Grund C.K. and Tulis M (2019) Facilitating student autonomy in large-scale lectures with audience response systems. *Education Tech Research Dev.* Printed online *https://doi.org/10.1007/s11423-019-09713-z*

Grzeskowiak, L.E., Thomas, A.E., To, J., Phillips, A and Reeve, E. (2015). Enhancing Education Activities for Health Care Trainees and Professionals Using Audience Response Systems: A Systematic Review, *Journal of Continuing Education in the Health Professions*, 35(4), 261-269.

Heaslip, G., Donovan, P. and Cullen, J.G. (2014). Student response systems and learner engagement in large classes. *Active Learning in Higher Education*, 15(1), 11-24.

Hoekstra, A. (2008). Vibrant student voices: Exploring effects of the use of clickers in large college courses, *Learning, Media and Technology*, 33(4), 329-341

Hoekstra, A. (2015). Because You Don't Realize How Many People Have Different Experiences than You: Effects of Clicker Use for Class Discussions in Sociology, *Teaching Sociology*, 43(1), 53-60.

Howe, N. and Strauss, W. (2000). *Millennials rising: The next great generation*. New York: Vintage.

Hughes, C. (2005). *Effective feedback, enhanced learning. In the 13th Improving Student Learning Symposium*. Centre for Bioscience Bulletin, St Andrews, UK.

Hunsu, N.J., Adesope, O. and Bayly, D.J. (2016). A meta-analysis of the effects of audience response systems (clicker-based technologies) on cognition and affect. *Computers & Education*, 94, 102-119.

Hussain F. N. and Wilby K.J. (2019) A systematic review of audience response systems in pharmacy education. *Currents in Pharm Learning & Teaching.* (11), 1196-1204.

Ismaile, S. and Alhosban, F. (2018). Students perceptions of audience response system in classroom feedback: A qualitative study, *International Journal of Advanced and Applied* Sciences, 5(4), 67-72.

Jones, A.G., (2019). Audience Response Systems in a Korean Cultural Context: Poll Everywhere's Effects on Student Engagement in English Courses. *Journal of Asia TEFL*, 16(2), 624-643

Kay, R. H., and LeSage, A. (2009a). Examining the benefits and challenges of using audience response systems: A review of the literature. *Computers & Education*, 53(3), 819-827.

Kay, R.H. and LeSage, A. (2009b). A Strategic Assessment of Audience Response Systems Used in Higher Education, *Australasian Journal of Educational Technology*, 25(2), 235-249.

King, S.O. and Robinson, C.L. (2009). Pretty lights' and maths! Increasing student engagement and enhancing learning through the use of electronic voting systems. *Computers & Education*, 53(1), 189-199.

King, S.O. (2016). Investigating the most neglected student learning domain in higher education: a case study on the impact of technology on student behaviour and emotions in university mathematics learning. *Problems of Education in the 21st Century*, 72.

Klein, K. and Kientz, M. (2013). A model for successful use of student response systems, *Nursing Education Perspectives*, 34(5), 334-338.

Kuhlthau, C.C., Maniotes, L.K. and Caspari, A.K. (2015). *Guided inquiry: Learning in the 21st century. Learning in the 21st century*. (2nd ed.). California: ABC-CLIO.

Lantz, M.E. and Stawiski, A. (2014). Effectiveness of clickers: Effect of feedback and the timing of questions on learning, *Computers in Human Behavior*, 31, 280-286.

Laxman, K. (2011). A study on the adoption of clickers in higher education, *Australasian Journal of Educational Technology*, 27(8),

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P.& Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS medicine*, 6(7)

Liu Q, Geerthuis, S and Grainger R (2020) Understanding academics' adoption of learning technologies: A systematic review. *Computers and Education.* (151)

Masikunis, G., Panayiotidis, A. and Burke, L. (2007). The use of electronic voting systems in lectures within business and marketing: A case study of their impact on student learning., *ALT-J Association for Learning Technology Journal*, 15(1), 3-20.

Masikunis, G., Panayiotidis, A. and Burke, L. (2009). Changing the nature of lectures using a personal response system, *Innovations in Education and Teaching International*, 46(2), 199-212.

Mathiasen, H. (2015). Digital Voting Systems and Communication in Classroom Lectures--An Empirical Study Based around Physics Teaching at Bachelor Level at Two Danish Universities, *Journal of Interactive Media in Education*, 2015(1), 1-8

Nelson, C., Hartling, L., Campbell, S., & Oswald, A. E. (2012). The effects of audience response systems on learning outcomes in health professions education. A BEME systematic review' BEME Guide No. 21. *Medical Teacher*, 34(6), 386-405.

Nielsen, K.L., Hansen, G. and Stav, J.B. (2013). Teaching with student response systems (SRS): Teacher-centric aspects that can negatively affect students' experience of using SRS, *Research in Learning Technology*, 21(1), 1-13.

Oblinger, D. (2003). Boomers gen-xers millennials, *EDUCAUSE Review*, 500(4), 37-47.

Patterson, B., Kilpatrick, J. and Woebkenberg, E. (2010). Evidence for teaching practice: the impact of clickers in a large classroom environment, *Nurse Education Today*, 30(7), 603-607.

Prensky, M. (2001). Digital natives, digital immigrants part 1, *On the Horizon*, 9(5), 1-6.

Prince, M. (2004). Does active learning work? A review of the research, *Journal of Engineering Education*, 93(3), 223-231.

Rana, N. P., Dwivedi, Y. K., & Al-Khowaiter, W. A. (2016). A review of literature on the use of clickers in the business and management discipline. *The International Journal of Management Education,* 14(2), 74-91.

Ruhl, K.L., Hughes, C.A. and Schloss, P.J. (1987). Using the pause procedure to enhance lecture recall, *Teacher Education and Special Education*, 10(1), 14-18.

Sheng R., Goldie C.L, Pulling C. and Lucktar-Flude, M (2019) Evaluating student perceptions of a multi-platform classroom response system in undergraduate nursing. *Nurse Education Today.* (78). 25-31.

Van Daele, T., Frijns, C. and Lievens, J. (2017). How do students and lecturers experience the interactive use of handheld technology in large enrolment courses?, *British Journal of Educational Technology*, 48(6), 1318-1329.

Velasco, M. and Çavdar, G. (2013). Teaching Large Classes with Clickers: Results from a Teaching Experiment in Comparative Politics, PS: *Political Science & Politics*, 46(4), 823-829.

Walsh, D. and Downe, S. (2005). Meta-synthesis method for qualitative research: a literature review, *Journal of Advanced Nursing*, 50(2), pp. 204-211.

White, P., Syncox, D. and Alters, B. (2011). Clicking for grades? Really? Investigating the use of clickers for awarding grade-points in post-secondary education. *Interactive Learning Environments,* 19(5), 551-561.