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

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Abstract

Do students' emotions and behaviours influence their learning in mathematics classes, and if yes, how and why? Based on a qualitative research design, evidence on how the use of Electronic Voting Systems (EVS) has influenced students' emotional and behavioural engagement with university mathematics learning is presented. The results show that the use of EVS enables students to diagnose their level of understanding of learning material, relative to the rest of the class. EVS use also helps, in real time, to stimulate, maintain, and re-focus student attention during mathematics instruction. A favourable perception of the learning environment as being altruistic appears to have influenced students to emotionally identify and align themselves with mathematics learning goals. There is enhanced interactivity in EVS-facilitated lectures, including positive student competitiveness, while the EVS anonymity utility also enhances increased student participation rates. However, a major disincentive to student engagement is the use of EVS-based mathematics questions with low cognitive demand. This research is a contribution to how specific educational technology-based interventions influence student engagement.
Key words: *emotional/behavioural engagement, digital natives, EVS/Clickers, engineering mathematics.*

Introduction

Technology is transforming the student learning experience. Across Europe, Africa, Asia and North America (e.g., Howard, 2012; Jaschik & Lederman, 2014; Keppell, Suddaby & Hard, 2015; Parr, 2013; Nkurunziza, 2013; Akue-Kpakpo, 2013; OECD, 2013, 2015a), and through innovative platforms, such as virtual schools and universities (Guo, Kim & Rubin, 2014), open educational resources (Nikoi & Armellini, 2012), big data and learning analytics (Oblinger, 2012; Petersen, 2012), and interactive polling (Voelkel & Bennett, 2014; King & Robinson, 2009a,b), technology is transforming both the student experience or engagement and associated learning outcomes (Stover et al., 2015; Bryne-Davis et al., 2015; Brady, Seli & Rosenthal, 2013; OECD, 2015b) across all subjects and disciplines (Puschmann & Bastos, 2015; Dalbello, 2011; Shapero, 2015; Thomson, Purcell & Rainee, 2013; Olive & Makar, 2009; Di Blas et al., 2014).

Moreover, the current and future generations of students or digital natives, who do not know what it means to live without the internet have 'a completely different type of relationship to the media' (Wong, 2015). The students we teach and can expect to teach are *emotive* and have an 'engrained instinct to share everything, including their personal data' (Elkin, 2015). For example, 'blogs have led to a complete reversal of the "diary" phenomenon – whereas once kids kept their feelings locked up in a book, today they (or at least many of them) prefer to post them online for all to see and share' (Prensky, 2012, p. 91). Other examples of digital natives' social media activities include "liking", "unliking", selfies (personal photographs), and interactive commenting on friends' feeds or activities. Hence, the engagement mode of the digital native student population with technology has a quite visible emotional component.

In contrast, the default mode of technology integration in undergraduate education eschews overt displays of emotion, while prioritizing cognitive engagement with learning, thus inadvertently enabling 'flight from feelings' (Gibbs, 2013, p. 12; see also Suarez-Orozco et al., 2015, and Zins & Elias, 2006) classrooms, especially at the university level. Yet recent research studies strongly indicate that the affective learning domain is indispensable to catalysing learning transfer or sustainable learning (Salcito, 2012; Stover et al., 2015; OECD, 2015b; Heckman & Kautz, 2014), and that considerations of student emotions and behaviours can create a "gateway to learning" effect on student learning outcomes (Cazzell & Rodriguez, 2011). So the goal in this article is to demonstrate through a qualitative research-based case study, how an educational technology such as interactive polling can be used to catalyse student engagement with learning mathematics through a description of the impact of the use of the technology on students' emotions and behaviour (i.e., the affective learning domain).

Case Study on the Impact of Technology on Affective Learning

This case study is therefore presented to highlight the *potential* and critical role that technology can play in catalysing digital natives' emotional and behavioural engagement with learning in both future classrooms and informal, out-of-school-or-university contexts. Therefore, this article will be focusing on the most neglected aspect of university student learning – the *affective domain* (Cazzell & Rodriguez, 2011). Specifically, the article will highlight, through a case study, the impact of interactive polling (clicker) technology on students' behaviour and emotions, as a measure of student engagement with learning mathematics.

Introduction: Electronic Voting Systems

EVS is an educational tool that can be used in a class, at its most basic level, in the same manner polling devices are used on the television programme, 'Who Wants to Be a Millionaire' (Ask the Audience section). The EVS technology typically consists of *handsets*, which are similar in shape, design and function to small television remote control units; a *receiver* or *dongle* that is essentially a USB device that is plugged into a computer port; and the *enabling software* which has to be downloaded to a computer. A lecturer uses the software on the computer to create (usually multiple choice) questions, which can be presented to students in class. The students answer the questions by clicking the corresponding alphanumeric answer choice on their EVS handsets (Figure 1).

Student responses are then displayed, also in real time, in the form of a suitable chart (Figure 1). The lecturer may then decide to elaborate on any relevant issues arising out of the question and answer display session.

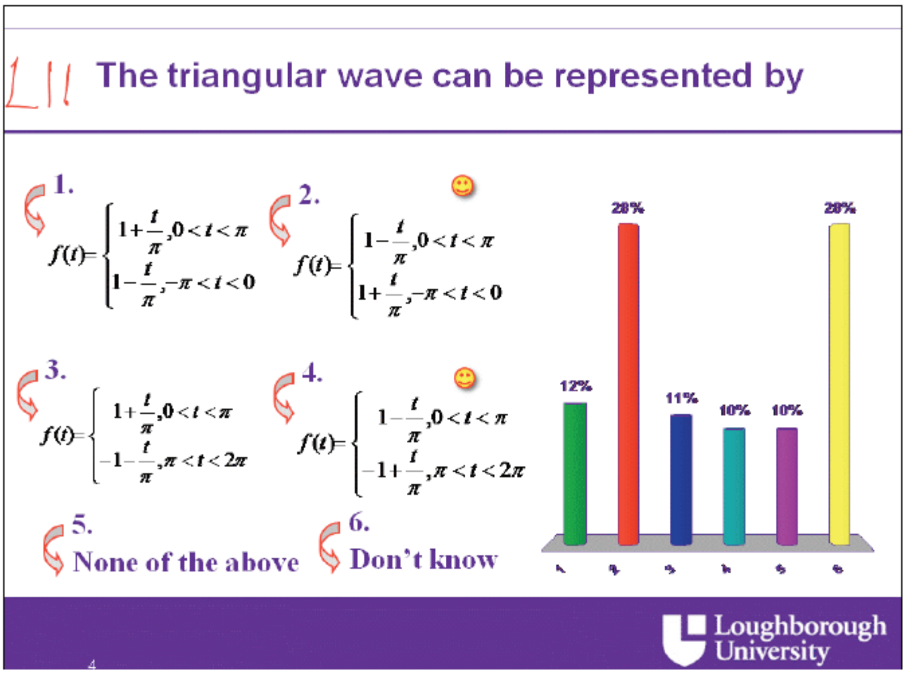

Figure 1: Chart showing the distribution of students' answers to an EVS question.

EVS is therefore a technology that affords an instructor the means to give students, especially in a large class, the opportunity to engage with course material by having them answer questions during a lecture, with subsequent provision of feedback to students. Moreover, this study specifically considers the use of EVS to support formative assessment, by aligning the EVS-based mathematics questions used with the anticipated student learning outcomes (e.g., see King& Robinson, 2009b; Beatty et al., 2006).

Correlation between the Use of Electronic Voting Systems and Student Engagement

In the most comprehensive review of the student engagement literature to date, Fredricks, Blumenfeld and Paris (2004) delineated engagement into the following three distinct yet interconnected dimensions of engagement: Cognitive, Behavioural and Emotional (p. 3; see also Duckworth & Yeager, 2015 and OECD, 2015b), with the Behavioural and Emotional Engagement constructs constituting the affective learning domain.

Student engagement is particularly critical in mathematics because it is a learning field that students often struggle with, and one that frequently generates feelings of apathy, alienation and inadequacy in students. This is one reason why there has been a proliferation of mathematics support centres in universities across the UK (e.g., Croft, 2002) and the USA (e.g., Shaqlaih & Celik, 2013; Ellis & Berry, 2012) to provide extra resources for students struggling with the mathematical components of their university courses. Moreover, research strongly indicates that engagement (Table 1) has a highly positive correlation with increase in student achievement and attendance or retention rates (e.g., Helme & Clarke, 2001; Fredricks, Blumenfeld, & Paris, 2004; Blumenfeld & Meece, 1988; Marks, 2000; Connell et al., 1995; Boyle et al., 2001; King & Robinson, 2009a). Research in mathematics education may therefore be 'strengthened if researchers integrate affective issues into studies of cognition and instruction' (McLeod, 1992, p. 575).

Further, research indicates that the use of EVS could significantly increase student engagement (e.g., Brady, Seli & Rosentahl, 2013; Byrne-Davis et al., 2015; Caldwell, 2007, Simpson & Oliver, 2007; Fies & Marshall, 2006). One study concluded that the most significant benefit of EVS use is the catalysis of student engagement with learning (King& Robinson, 2009a).

However, student engagement, specifically in relation to EVS use, has often been defined narrowly; with studies purportedly evaluating engagement mostly focusing on the impact of EVS use on student attitudes or participation in class (e.g., see Simpson & Oliver, 2007). Consequently, this article will highlight the relationship between the use of EVS and the affective learning domain in stimulating student engagement with learning by focusing on the following more comprehensive emotional and behavioural engagement constructs:

- Student Attention
- Student Comparison of Academic Performance
- Surface (Lecturer-Student), Peer and Technical Interactivity
- Instruction to Stimulate Positive Learning Challenge
- Student Perception and Response to Altruistic Instruction, and
- Anonymity
- Disadvantages of Using EVS
- Engagement Interconnectedness

Significance of Research

One of the conclusions of the comprehensive review of engagement literature was the need for 'studies of interventions' (Fredricks, Blumenfeld, & Paris, 2004, p. 87) that may help illuminate the 'development or malleability of engagement' (p. 87) to specific educational interventions. This study meets this need by highlighting the use of EVS and associated questions to facilitate emotional and behavioural engagement within the disciplinary domain of university mathematics.

Further, the authors also called for the adoption of a qualitative approach to measuring engagement, which would provide 'thick descriptions of classroom contexts' about the factors that influence engagement (p. 86). Again, this study meets this criterion as the descriptions of engagement provided are based on evidence from interviews with students, supplemented by classroom observations and observations of students working on specific tasks in the interviews conducted.

Table 1. Aspects of student learning that have been influenced by high levels of student engagement (Source: Fredricks, Blumenfeld, and Paris (2004), Boyle et al., (2001), and King and Robinson (2009a).

#1 Academic achievement
#2 Student boredom and disaffection
#3 Attendance and retention rates
#4 Attitude to learning
#5 In-class participation

Methodology of Research

To answer the research question, 'How has the use of EVS impacted (or otherwise) *student engagement* with respect to the learning of mathematics at university?', a research study predicated on a *qualitative* research methodology was conducted. Further, a semi-structured interview approach was employed to interview 10 volunteer students. As a result of the preliminary studies conducted (e.g., King & Robinson, 2009a,b), substantial knowledge on the ways that EVS use may influence student learning had been acquired. However, there were still gaps in that knowledge. Therefore, the semi-structured interview approach was adopted as the most effective means of addressing these 'gaps' (Cohen, Manion & Morrison, 2007, p. 354). Further, this research assumes an *interpretivist* approach because this study is focused on presenting the interpretations of respondents about learning mathematics with EVS. Therefore, the research accounts presented are constructions rather than definitive conceptualisations of respondent learning experiences with EVS.

Sample and Sampling

The target population for the research was second-year Automotive and Aeronautical Engineering students (n = 150) who were taught an engineering mathematics module in the 2008/2009 academic year; an explanation about why this research is still relevant seven years later is presented in the Discussion section. Six male and four female Automotive/Aeronautical Engineering students volunteered for the interviews (the synonyms, K1 to K10, have been adopted to protect the privacy of the 10 student interviewees). The Engineering students were identified as the primary target for purposive sampling principally because this cohort of second-year engineering students had been introduced to the use of EVS in their first year mathematics modules. It could thus be expected that their views on EVS use would be more mature or at least be immune to an extent from the novelty effect of EVS use, than students who had just been introduced to EVS. Therefore, the sampling approach that was implemented was *purposive sampling* (Bryman, 2008, p. 458).

Method

Semi-structured interviews were adopted to interview the 10 Engineering students who volunteered to participate in the research. This approach is sufficiently structured to enable consistency, i.e., all interviewees were presented with the same sets of questions, and yet flexible enough to capture nuances and unanticipated students' comments and insights (Bryman, 2008, p. 438). A sample of the interview questions is presented in Table 2.

Table 2. The interview questions.

#1 GENERAL QUESTIONS
• What are the disadvantages/problems (if any) of using EVS in lectures? • What are the benefits (if any) of using EVS in lectures? • Were there times you did not vote in class? • Does EVS help you think more about a question or topic? How? • How do you feel when an EVS question (i.e., because it's too hard or easy) puts you on the spot? • Any other comments?
#2 QUESTIONS ON FEEDBACK
• What happens when you get questions wrong? What do you (usually) do then or later? • What are your views about the [instructor] feedback you get? Does it help you identify clearly where you went wrong, show you how you can get it right the next time, enough time for feedback? • Multiple select effect? • Response range effect?
#3 SPECIFIC EVS MATHEMATICS QUESTIONS
• What's your approach to solving maths questions? To EVS-type questions? • Do you recall this question (e.g., Figure 3) • How would you solve this problem? • What happens when you see a question on double integrals? • Which aspect (if any) of the questions did you have difficulty with?

The interview questions also included specific EVS questions (e.g., see '#3' in Table 2, and also Figure 1) that had been used during lectures for the engineering mathematics module class, on which all the interviewees were enrolled. The questions were based on the topics that had been covered in class, including Multiple Integration, Fourier Series and Vector Calculus. The main rationale for the inclusion of the questions was to assess whether and/or how the use of EVS questions had influenced student engagement with learning on the engineering mathematics course.

Analysis of Interview Data

To analyse the data from student interviews, *thematic analysis* was adopted, and this facilitated the identification and grouping of relevant themes and sub-themes, with the organisation, structure and presentation of the themes dictated, on a macro scale, by the research question, and at the micro level, by the interview questions. Using questions to guide the analysis 'is a very useful way of organising data, as it draws together all the relevant data for the exact issue of concern to the researcher, and preserves the coherence of the material' (Cohen, Manion & Morrison, 2007, p. 468). The analytical structure adopted is presented in Table 3.

Table 3. A simplified description of the analysis structure adapted for this study.

Overview of the Data Analysis Protocol
• **#1** Research and interview question-guided thematic analysis approach (Cohen, Manion & Morrison, 2007:468; Bryman, 2008:554)
• **#2** Data collection intentionally structured to meet research objectives via adoption of semi-structured interview approach and design of interview protocol
• **#3** Exhaustive reading and manual annotation of individual interviewee transcripts
• **#4** Coding of interview data with respect to the three macro themes – Cognitive, Behavioural and Emotional Engagement
• **#5** Coding of interview data with respect to the constituent micro themes under each of the three macro themes (e.g. micro themes under Cognitive Engagement – Deliberate Practice, Relative Performance, etc; Behavioural Engagement – Attention; Emotional Engagement – Perception of Learning Environment)

Trustworthiness

To determine the reliability and objectivity of the research, the following Trustworthiness criteria (i.e., Lincoln & Guba, 1985): *Dependability* (which parallels Reliability) and *Confirmability* (which parallels Objectivity) were adopted (see also Bryman 2008, p. 377).

To ensure dependability and confirmability, an audit approach, i.e., ‘keeping complete records of all phases of the research process’ (Lincoln & Guba, 1985, p. 317), was adopted. These records include the spreadsheet/table used in recruiting interviewees, the interview protocol consisting of all the materials and questions used during the interviews, audiotapes of the interviews in virtual formats, transcripts of all interviews, documents detailing the thematic analysis techniques used in making theoretical inferences and the documents (i.e., analysis templates) produced as a result, and draft copies of this article. Further, draft versions of this article have been submitted to relevant academic personnel for review, with the manuscript updated based on the feedback received.

Other Validity Measures

To ensure *face validity* for the interviews, the interview materials were submitted to senior faculty members for review. Sections of the data analysis protocol had also been piloted with another group of students (Sports Technology) at the host university.

To minimise bias due to the *acquiescence factor* (Cohen, Manion & Morrison, 2007, p. 151), interviewees were reassured at the beginning of each interview session that all their contributions would be treated with confidentiality. For example, all student interviewees had to sign a Consent Form that guaranteed their privacy, and freedom to withdraw from the research study at any time during the research process. Further, it is essential to clarify that the researcher who interviewed the students had not taught or planned to teach them or their class, and also did not have direct access to these students As indicated in Table 2, the interview protocol often directly required students to elaborate on the perceived disadvantages of using EVS, and not just focus on the benefits.

Results of Research

Behavioural Engagement - Student Attention

The research results that are presented in this section will focus on how the use of electronic voting systems has influenced three dimensions of student attention.

Stimulating Student Attention

In the excerpt below, K9 talked about how the sight of EVS handsets at the beginning of a lecture and the association of the handsets with questions to be asked in class created a feeling of 'anticipation' or eagerness about the lecture. In fact, s/he prefaced this by implying that the atmosphere or ambience around a 'voting system lecture' was remarkably different from conventional lectures in a positive way:

> *K9: You can tell when, we've had, like, a voting system lecture, because everyone comes into the room and sees the voting system. And everyone's sort of a bit more on edge, and, you know, anticipation about, 'oh, I've got to pay attention because, like, there's going to be a question coming up'. Whereas before, it was just, like, 'oh, I'm just copying down this note, and the next note, and the next note'.*

K8 also talked about how EVS use made students 'focus on the lecture', and contrasted this with the scenario in other lectures where students were in the habit of falling asleep in class (and implied that this did not happen in EVS-enabled lectures):

> *K8: Mm, when you compare a similar scenario with another lecture where they don't use voting systems, people just come to the lecture and sleep, you know? To be honest. And during voting systems, at least that doesn't happen, you know? Even if they're not listening when the lecture's going on…*
> *I: Yes. ["I" is the interviewer, i.e., the author]*
> *K8: When they see a question, they start working it out, you know? As in, they start, you know, on the paper, they start something, you know? So it's better than not doing anything at all.*

Maintaining Student Attention

The results indicate that EVS use, especially when the questions are spread throughout a lecture, may help maintain student attention. In the excerpt below, K1 implied, in a positive way, that the instructor often deliberately asked students questions just 'to make sure you've been listening', in order to ostensibly maintain student attention:

> *K1: Yeah, just at any time during the lecture, [instructor]'ll just spring us, bring a question up, so, to make sure you've been listening.*

Similarly, K4 talked about how the timing and the use of EVS questions helped 'break the lecture up a bit', and how this helped his/her concentration in class or to put it another way, got 'his/her mind active again':

> *K4: They break it, they break the lecture up a bit and I find, that obviously your concentration can then be distracted away from the visual, from learning on the board. And then you can actually do something, do something yourself, get your mind active again and then obviously you can listen for the next 20 minutes again.*

Meanwhile, K2 stated that s/he found that the usually limited time allocated for voting often helped him/her to concentrate on a question in order to get the right answer:

> *K2: It can only help for you to concentrate. Because the thing is you know that you're being given 30 seconds to solve this, for example. You're being given 30 seconds and you have to concentrate and then you have to vote. So it is related. 'Cause you... Because of the time limit you have to concentrate on the question and then you have to vote quickly so that you get it right.*

Re-Focusing Student Attention

In the excerpt below, K4 talked about how getting a question wrong was a sort of reality check that brought home the message, 'I actually haven't listened at all today', and how this tended to make him/her feel more accountable about paying attention in class:

I: ... but this one, you're given a question maybe after A's just done a topic and A wants to find out how well you got it.
K4: Yeah. It makes you realise, like, if you've actually been listening or if you've just been sitting there, and, you know, on auto-pilot. And, like sometimes when A's put a question up, I'm like 'I actually haven't listened at all today'. Like, what am I doing, why am I here if I'm not going to listen. Like, it kind of makes you, like, it kind of holds you accountable in a way, like, your attention span.

Getting a question wrong in class seemed to have the same effect on K7 as it had on K4. K7 stated that getting a question wrong would make him/her think, 'I should have paid more attention'. However, s/he pointed out that this was usually followed by the desire to make up for the inattention by reviewing his/her notes alongside the feedback from the instructor:

I: What about, if before a question came up, for one reason or another, you were switched off and thinking about something else. You were not paying attention to that particular topic and a question comes up – what happens?
K7: Um, I always think 'I should have paid attention', but then it helps because I'll have to look through the notes I've taken, and if I still don't quite get it, then A will go through it and then, it just makes it really.

Summary: Student Attention

In summary, the use of EVS for mathematics instruction in real time has helped to *stimulate*, *maintain* and *re-focus* student attention in class in the following three ways:

- EVS use helps to *stimulate* student attention. EVS use makes students pay attention during a lecture because they know they are going to be asked a question, usually about the topic presented in class.
- EVS use helps to *maintain* student attention. EVS questions may be used as a way of managing a lecture by presenting the questions at carefully selected intervals in order to defuse boredom and monotony.
- EVS use helps to *re-focus* student attention. If a student had not been paying attention prior to the administration of a question, this serves as a wake-up call to the student i.e. highlights the inattention and also what is required to remedy the situation.

Behavioural Engagement - Student Comparison of Academic Performance

Another feature of EVS usage, the display of answers to a question in a format that is viewed by the whole class (e.g., Figures 2 and 3), helps illustrate how an individual student may use this statistic to diagnose their level of understanding and performance relative to the class. In his/her submission, on the pre-interview questionnaire for instance, K1 talks about the power of the EVS answer display spread to illustrate relative performance:

K1: Allows you to answer questions to see if you are at the same level as the rest of the group.

This information about relative performance provides a powerful diagnostic tool to the student – a reference point. It could be argued that a feedback type that includes this reference score is much more useful to students than those without (e.g. individual test scores or grades without any reference points, teacher claims about student performance without any referential benchmarks, etc.). For example, K2 stated that information about relative performance was critical because the 'competitive' nature of the class required this knowledge:

I: You said, 'It lets you know where you need to work more', for instance – why is that important?
K2: It's important that you... you know, if you're doing engineering, it's very competitive, so you always have to know how the other students are doing. And by that you actually know, and then sometimes you actually feel good about yourself that you did well.

Similarly, K4 clarified the importance of having information about how the rest of a class performed on an EVS question, by commenting that access to this information would either bring reassurance or highlight the need to take corrective measures:

K4: It just, like, 'cause if you're constantly getting a different answer from everyone else, you're the one with the little bar going '4% answered this' and it's wrong, or then on the other hand, like, say, you're the right answer and only a few people have got it, it makes you kind of, like, feel good about where you are.
I: Yes
K4: But like, in general, like, most of the time you all get the same answer and it makes you feel. It reassures you that you're, like, on the same pace as the rest of them. I think if you were struggling, say, if you were constantly getting a different answer to everyone else. It would make you, like, It's kind of anonymous as well, it would make you, it would make it easier for you to go and approach the teacher and say 'look, you know, I'm struggling here'.

Moreover, K4's comments seem to suggest that information about areas of 'struggle' would trigger proactive action from the student with respect to approaching the instructor outside the classroom. This is perhaps an indication of how information about relative performance, which is predicated on deliberate practice, may be a catalyst (Draper, 2009) for learning beyond the classroom, especially to address gaps in understanding.

Behavioural Engagement - Interactivity

Interactivity in EVS-enabled lectures refers to the use of questions to actively engage students in the learning process, instead of them being passive recipients of information transmission from the lecturer. Based on classroom observations and interview data, EVS use has the potential to catalyse two levels or modes of interactivity in mathematics classrooms. These interactivity modes are: Lecturer-Student Interactivity, Peer Interactivity, and Technical Interactivity.

Lecturer-Student (Surface) Interactivity

This is the interaction between the student(s) and instructor, i.e., instructor poses a question which students respond to by answering, and which the instructor then responds to by providing feedback. This sets up a chain of interactivity between student and instructor, which is not a typical feature of contemporary university mathematics lectures. But this occurs at the surface level because the mode of communication is limited, and mostly instructor-driven and/or initiated.

In the excerpt below, K8 talked about how the use of EVS 'changed' what usually happens in a mathematics lecture, in that students had the opportunity of interacting with the instructor, via the EVS question and answer sessions:

K8: Because of the others' interaction, you know? There's interaction between the students and the teacher.
I: What kind of interaction?
K8: Um, answering. Like, what basically happens if A asks a question...... we'll be asked to answer.
So, directly, we may not be answering, but we use the voting system.
I: You've got that contact to give a response back.
K8: Exactly.
I: So, that doesn't happen in other lectures?
K8: No, it doesn't. Very few. It's only when a person raises an arm and asks a question is there interaction between the student and the teacher.

K5 had also written on the pre-interview questionnaire, that one of the ways that EVS had 'helped' was that it provided an avenue for 'more interaction with the lecturer'. More evidence for surface interactivity is not presented here because research evidence (e.g., Simpson & Oliver, 2007) clearly indicates that this is the most common form of interactivity enabled by the use of EVS.

Peer Interactivity

This is the interaction between students. Class observations show that this interaction occurs when students compare their answers with their neighbours after voting, talk through a problem with a classmate before voting, or in a limited sense, on the few occasions when the instructor asks the students to discuss their answers with their neighbours.

The instructor would often encourage students to talk to their peers in order to challenge one another about the rationale for the answer choices selected in response to an EVS question. However, the instructor would typically only instigate this kind of discussion when the class response indicated a lack of consensus e.g. a question in which only 50% of the class got it right, as K9 describes in the excerpt below. It should be noted that in this particular class, students often sat with their friends, and so peer interactivity in this context is contingent on existing group dynamics. Students were more likely to chat with their friends knowing that they would not be ridiculed or embarrassed if their knowledge of the mathematical topic under discussion was below par:

K9: Whereas if it's more sort of 50/50, then occasionally I'll say 'ok, who voted for this, who voted for this and then talk amongst yourselves...... to sort of try and convince the other person why it's that one'. And then we'll go over it so you know roughly why, even if the answer was wrong from your part, then you'll know why the other person thought that answer was right or... So it's quite, it's quite good talking about it every now and then, 'cause even if the answer's wrong, you know why someone would have voted for that.
…….I found it, mm, quite helpful because normally I sit with my friends, so even if my answer's wrong, it didn't really matter.
….Um, I don't think it would work so well if, you know, you're split into groups or anything, because I don't, I know other people in my class, in my group are cleverer than me, so it's not always nice knowing that they're always right and you're always wrong.
But when you, when it's with your friends, it, it's quite nice to think 'oh well, they voted for that one for a reason'...

Generally, most interviewees appeared to talk to their peers about the EVS questions, only after they had worked on a problem and submitted their own answers. K5, for instance, describes how s/he would vote and afterwards ask a peer, 'what did you get?' S/he also alluded to the group dynamics inherent in the classes where 'it's usually small groups of us [i.e. friends] sitting together' and 'looking at each other's work' to discover if anyone had a different answer and probably talking about why that was so:

K5: Um, usually I would vote first and then ask them 'what did you get?'
……….Yes. I think most of the time what tends to happen in our lectures is – I don't know whether it's just us – but it's usually small groups of us sitting together...... usually we would answer and then, um, if one of us, or if we get a different answer, we look at each other's work and work out how, you know, who has gone wrong and why.

K10 also talked about how s/he would vote first and only then talk to his/her peers to avoid being influenced:

I: Are there times in class when you wanted to vote, you talked to the guy sitting next to you or the guy sit, your mate or people who seem to be close to you before you answer the question or after you answer the question?
K10: Um, I think, you kind of, I go and answer it first, and if you talk to somebody else, in case you can change it, you've always got the option of –
I: So you're just asking 'what have you got?'
K10: You're, like, being influenced by other people.

It should be noted that although some level of student-student interaction i.e. students talking to each other in class occurs at least sporadically in most conventional mathematics classes, EVS use assures a higher frequency/structure and more learning-focused occurrences of this type of interactivity. In the excerpt below, K9 stated that although s/he usually sat with a group of friends, s/he would 'normally' vote first, and only talk about how s/he voted afterwards with his/her friends:

K9: Normally, normally we'd click...... and then, like, talk to the people next to us and say 'oh, I got, I said B' Um, but normally we vote and then... ... talk about it afterwards.

Peer interactivity appears to infuse an element of positive learning challenge or competitiveness into the voting process. In the excerpt below, K4 talked about how s/he would often wait impatiently for the instructor to close the polling and for the results to be revealed because of his/her anticipation or excitement at seeing whether s/he got the answer right. Similarly, s/he talked about how s/he would ask for the answers that his/her friends selected as a sort of competition to see whose answer would be revealed to be the right one:

K4: I want to know if I got it right or not, you know.
I: Yeah. Ok. So there's anticipation to know whether you got it right or wrong.
K4: Yeah. It's exciting, it's like, 'oh god'.
I: 'I'd better get that right... how the rest of the class do?'
K4: Yeah. I'd be like 'I got that right, yeah'. Or, like, before your friends are done, you're like 'what did you get or what did you get' or you've got two different answers, it's like 'I bet I'm right, I bet I'm right' and it's like 'yes'.

K8 also talked about how this element of challenge when s/he stated that s/he would often ask his/her friend, after voting, about the answer s/he had selected 'just to see if s/he was right or wrong':

I: Ok. After you've voted, you don't ask them to see 'what did you get, do you, what was your answer?' You don't, you don't usually ask?
K8: Um, before the answer comes up or after the answer comes up?
I: Before or after.
K8: After, I do.
I: You do.
K8: After. When it, suppose we get 75% for A and 35% for B... ... or something like that, you know?
Then I'll ask the person sitting next to me what he got, you know? Just to make sure, just to see what he would have thought, you know? Just to see if he was right or wrong.
I: Ok. Why do you want to know that?
K8: Just 'cause he's my friend, so -

Technical Interactivity

This may be defined as the interaction between students and the EVS handset – the students get to 'do something', although this usually translates into merely clicking a handset. Its significance might be that the physical action of a clicking a handset could perhaps help reignite student interest or attention. As this form of interactivity, has a limited impact on behavioural engagement, no evidence of this interraction mode will be presented.

In summary, another facet of behavioural engagement that EVS use has influenced is the level or mode of interactivity in lectures. The question-and-answer sessions provide a level of instructor-student interaction that is otherwise absent in typical mathematics lectures. Moreover, the question sessions are often structured in a way that allows students to interact with each other. One expression of this is the element of challenge that peer interaction introduces into classroom dynamics, i.e., students want to see if they can do better than their peers.

Emotional Engagement

How has EVS use influenced how students *feel* about engaging with university mathematics instruction? In this section, evidence on how EVS use has impacted emotional engagement, with reference to how students perceived the instructional environment, will be presented.

Student Perception and Response to Altruistic Instruction

Research on EVS indicates that students typically have positive attitudes about the use of EVS in mathematics lectures (e.g., Simpson & Oliver, 2007; Bruff, 2009), so this section is not about that aspect of emotional engagement. Instead, I will focus on how students appear to perceive an EVS-enabled instructional environment as one that is to a large extent intentionally or altruistically designed to aid their learning.

For example, K7 implicitly alluded to this favourable perception of the altruistic nature of the instructional environment when s/he stated that s/he would only adopt educated guesswork in answering questions in class, so as not to provide the instructor with unreliable feedback on student progress:

I: You don't like selecting the 'I don't know' option [i.e., to discourage guesswork].
K7: No I don't. I'd rather, even if it's an educated guess, I don't like guessing unless it's educated, because, especially as [instructor] does use it quite often to see how we are doing and to see what we need to put more work into in class...
I: Yes.
K7: ... um, I think if you luckily guess the right answer and you don't know it, it could affect that if

many people have done it. And [instructor] might think 'oh, the class knows what they're doing' and we've guessed it. So I try not to guess if I can help it.

Similarly, K4 reiterated the position that it is important for the instructor to have accurate feedback about student knowledge, based on an implicit assumption that the instruction is directed at helping them learn and review areas they might be struggling with:

I: Suppose they have an 'I don't know' option – do you go for that instead of guessing?
K4: No. I don't think 'I don't know' is very helpful on it. Like, not if you know anything. But I guess it is, 'cause, like, it shows [instructor] who, if, like, people actually don't know. And it would probably make [instructor] more likely to go through a question if lots of people don't know.

Further, the EVS systems are solely used for formative assessment. For example, K2 stated that s/he usually took the EVS tests i.e. answering the questions in class seriously because 'that tells me where I'm standing in class', although s/he acknowledged that not all students emulated his/her approach:

I: And coursework too, if you do it well, it helps you with your final grade. But the [EVS-based mathematics] questions that get put up in class, you don't want to get graded for that.
K2: No, you don't.
I: So does that affect your attitude towards the questions? I mean, do you take them seriously or?
K2: Yeah, I do take them seriously. Because that tells me where I'm standing in my class.

Anonymity

In the two excerpts below, K1 talks about how the anonymity aspect of EVS use helps with confidence and allays student fears about being put on the spot:

I: And this question says 'in what ways has the use of voting systems in MAB104 hindered or helped your learning of additional calculus?' And you said it helps you to answer anonymously, so nobody needs to know what you... ... how you answered. Why is that important?
K1: Um, because you don't always have the confidence to put your hand up if you don't know whether you're right or not. But it lets you do it without anybody else knowing.
I: Or even, doesn't that put you on the spot sometimes? It's been so long, and then it's something you're also going to do in the future, so you might not have enough information.
K1: It does. But because there's the anonymous handsets, it's ok. I wouldn't like A to do this and then come over to you and say 'right, what's the answer?' Because that would put me on the spot. Because it's anonymous and also because A puts 'I don't know' there as well as an option...

The deployment of new or interactive technologies in new situations, whether for learning or other purposes, could be expected to evoke positive feelings due to the novelty of the technology. So it is pertinent to point out that the students whose comments about the emotional aspect of learning with EVS are being presented in this section are not new to the technology, having been taught in a first year university mathematics module by an instructor who used EVS in the class. Consequently, the novelty factor exerts much less influence on the feelings of students about EVS use presented here.

In the excerpt below, K7 talks about how EVS use was introduced in a first year university mathematics module, and how s/he initially found the technology 'intimidating', but later became familiar with the technology because EVS was regularly used in class:

I: What did you like? Don't mention the names of the lecturers. What did you like about the two modules? What stood out for you, I mean, the way they lectured?
K7: Um, they, um, the first one covered what I'd either done at A level, A level maths or Further Maths.
I: So it was an addition?
K7: Yes. It was a nice break from the other subjects which were brand new, and it's nice to recap. Um, the second one was more new topics, which was nice, but also, um, we started using the voting systems from then.
I: Ok. The one on voting systems, the one on voting systems, so this is not your first introduction to voting systems...
K7: No.

S/he also stated that s/he had talked about EVS use with peers from other universities who thought that classroom voting was a 'good idea':

K7: At first it was a bit intimidating 'cause you didn't know, the very first question, you didn't know how it was going to work... ... even though you're pressing it anonymously and obviously, it was anonymous. It was just things going through my head. But once we started using them and I found them helpful, it was, the beginning of every class, pick one up and just use them throughout.
I: So what do you think - you used voting systems in first year, you're now using them in second year – how do you feel about this? Is it something you've welcomed, in the sense that part of your learning, I mean, you welcome it in a way now.
K7: Yeah. I like it and I've mentioned it to people studying similar courses at other universities, and when I've mentioned that we vote in class, they've all been surprised 'cause they don't do it. And they've said it sounds like a good idea and it's definitely something I personally like.

Disadvantages of Using EVS

As part of the interview protocol, interviewees were asked to comment on any negative aspects or disadvantages of using EVS in lectures that they had experienced or observed. In addition, the interviewees also often commented during the course of the interviews, without prompting from the researcher, about aspects of EVS that they considered to be potentially disengaging or disadvantageous. Due to volume constraints, a summary of these disadvantages, based on descriptions provided by interviewees and supplemented by interviewee observations, is hereby presented:

1. **EVS Malfunction:** These include technical, i.e., EVS handset and software malfunction.
2. **Non-Voting:** This includes issues surrounding the logistics of distributing handsets before lectures, low student participation in some EVS QA sessions, and sufficiency of voting time;
3. **Usage:** This includes issues around the perception of some questions/distracters as being sloppy or ineffectual, guesswork, student swapping of answers, flippant attitude towards voting, and the feeling that some lectures are 'rushed' due to EVS use.

The enumerated disadvantages, for instance, software and hardware malfunction, occur sporadically. Moreover, technical expertise and confidence with using technology usually increases with time (King & Robinson, 2009a). An aggregation of the student comments also indicated that the time allocated for voting was usually sufficient, and that EVS use for voting did not have a negative impact on lecture time, except towards the end of the semester. Further, the cases of reported flippancy towards EVS use and swapping of answers seemed to have been limited occurrences.

In summary, the most important disadvantage mentioned or the one that could have potentially high influence on student engagement with learning is the use of 'sloppy' questions and/or distracters. In answering one of the EVS questions posed during the interview, which had also been used in class, K2 pointed out that the distracters (i.e., answer options) were too obvious, and that other options could have been used to make the question more challenging:

K2: Well, this is where the disadvantage of the voting system comes in 'cause there's only one answer up there with 2 – y. Whereas I'm thinking, for the same example, the same question, was up there with the 2 – y on the first integral, not on the second integral, I think you might get a few more people going 'ah'.
I: Which one?
K2: And making them think 'do I switch it?' But obviously for me looking at that I can say that, but that's the disadvantage to this method. Whereas if that was a little bit closer for this example, number 4, um, the first integral was 0 to 2 – y, I think you'd probably get better results between 3 and 4 for that reason.

Discussion

The results that were earlier presented were based on research conducted in 2009. So this is a pertinent question: Why was the research nor published before now, and is technology now a significant lever in influencing students' emotional and behavioural engagement with learning? The reason the research presented here is more relevant now (i.e., in 2016) is because there has been a significant shift and perceived value on the role that emotions play in influencing student learning outcomes at both the school and university levels (Wong, 2015; Salcito, 2012). Moreover, technology, especially web-based systems and social media, are now recognized as primary influencers of young people and students emotions and behaviours. This is why some of the research results presented are still relevant for understanding and designing learning tasks that will facilitate positive student engagement with learning.

For example, the use of laptops and mobile phones during classroom instruction for playful purposes that are separate from the learning goals for that class can be very distracting. Therefore, attention still plays a pivotal role in (mathematics) classroom discourse. Various researchers have examined, for example, the role of attention in helping students learn algebra via specialised computer software (Hewitt, 2009) and the interplay between attention, instructor pedagogical practices and student engagement with the learning process thus engendered (e.g., Mason, 1989; Ainley & Luntley, 2007; Wilson, 2009). Further, research evidence suggests that it is hard to maintain attention, within the context of a lecture or presentation, beyond 15 to 20 minutes at a time (Middendorf & Kalish, 1996; BBC, 2010); although Wilson and Korn (2007) disputed the supporting evidence, but not the reality of the attention span itself. Moreover, the current generation of students also known as digital natives, or the Google generation are notorious multi-taskers (e.g., JISC, 2007; Oblinger, 2008) who find it difficult to concentrate on any one thing or task for a considerable length of time.

Similarly, the favourable perception of the EVS-enabled instructional environment as being altruistic is significant because research evidence suggests that students are more likely to engage with learning (and also refrain from cheating) when they 'felt their teacher was more concerned with investing in student learning than [in] certification via testing' (Palazzo, Lee, Warnakulasooriya, & Pritchard, 2010). In summary, a favourable perception of the learning environment as being altruistic appears to have influenced students to emotionally identify and align themselves with the goals and responsibilities expected of them in learning situations within that environment.

Likewise, anonymity is still a valued pedagogical affordance because research evidence suggests that, compared to conventional classes, a greater number of students actively participate in EVS-enabled classes, as measured by the number of students who respond to the (EVS) questions posed in class (e.g. Fies & Marshall, 2006; Bruff, 2009). One reason for this is that students could answer questions without their peers knowing how they answered or what choices they selected. This anonymity feature thus helps increase the confidence of students in volunteering answers to questions posed by an instructor.

Meanwhile, it is important to highlight the possible reasons for the favourable student perception of the positive learning affordance of the use of EVS. The favourable perception of the EVS-enabled instructional environment as being altruistic is perhaps attributable to two reasons. First, students in the United Kingdom typically do not have to pay to use the handsets. So the handsets are more likely to be seen from an altruistic perspective. In contrast, students at many institutions in the USA typically have to pay to use the EVS systems (e.g., King& Robinson, 2009a), and this often has a negative correlation with the perceived educational value of using clickers for instruction (e.g., Bugeja, 2008).

Moreover, classroom observation of EVS use in lectures lends credence to the notion that student interest in EVS use appears to have moved beyond the initial or transient, 'situational' interest phase, based on the novel attraction of the EVS contraption, to a more stable orientation or 'personal' interest phase (Krapp, Hidi & Renninger, 1992). This is being inferred because students apparently still displayed positive attitudes towards EVS use, despite having been exposed to the technology for two academic years. More recent research (e.g., OECD, 2015b; Stover et al., 2015; Voelkel & Bennett, 2014) also buttresses this claim.

One question that may be asked is how the different elements of engagement interact. A valid response to that question would be that emotional, behavioural and cognitive engagement are interrelated. The presence of one influences the other two and vice versa (Fredricks, Blumenfeld, and Paris, 2004, p. 61). Moreover, students who are not engaged will not learn (Watson, De Geest, & Prestage):

> *There is a connection between engagement and learning; students cannot learn unless they are engaged, and engagement is a combination of social, emotional, intellectual and task characteristics. Teachers had to work on all these facets to ensure engagement. All teachers believed that learners' concentration and participation could be developed (p. 12).*

However, it should be noted that the interplay between engagement and learning is a complex one and incorporates or necessitates a detailed consideration of themes such as beliefs (e.g., teacher's, student's and self-efficacy beliefs), motivation and metacognition.

In addition, research in the field of engagement and mathematical thinking is considering how 'personal meaning, teachers' emotional knowledge (emotional skills) [and] humour' (Hannula, Panziara & Waege, 2009; see also OECD, 2015b) as engagement constructs may influence mathematics teaching and learning. However, a detailed investigation of these issues is beyond the scope of this article, although aspects of motivation, using goal theory, will be employed in characterising student approaches to learning mathematics in a future study.

Conclusions

This research study was designed to provide insights on the research question: How has the use of EVS impacted (or otherwise) *student engagement* with respect to the learning of mathematics at university? This research question has been answered through the presentation of evidence from interview data about the impact that EVS use has had on *behavioural* (i.e., student attention; student comparison of academic performance; interactivity; learning challenge) and *emotional* engagement (anonymity and altruistic instruction).

The results show that the EVS utility for students to be able to answer questions anonymously has an enormous impact on the numbers of students responding to questions in class. Anonymity helps remove or reduce the fear of being labelled stupid or being embarrassed in front of peers, in the event of getting a question wrong.

The findings also show that EVS use appears to help in stimulating student attention because of the realisation that they will subsequently be asked questions after the presentation of a topic in class makes them alert and to pay attention during instruction. Similarly, the results of the question and answer sessions can help to re-focus student attention by highlighting areas of learning deficiencies. Further, instructors can strategically use questions at definite intervals during a lecture to maintain student attention.

Further, EVS use not only facilitates increased student participation in mathematics lectures, it also enhances the mode and frequency of interaction that students have with their instructor, one another, and the EVS tool. Hence interactivity is significantly increased. This enhanced interactivity in turn catalyses a classroom atmosphere that is characterised by a positive student competitiveness to get answers right and compare their answers with peers during classroom voting on mathematics problems. Similarly, the display of answers to EVS questions in a format that is viewed by the whole class enables individual student diagnosis of the level of their understanding and performance, relative to the whole class.

Last, students appear to have a favourable perception of the EVS-enabled instructional environment as being altruistic. This favourable perception in turn appears to have influenced them to emotionally identify and align themselves with instructional goals.

But students' comments show that EVS use is not entirely beneficial, as EVS technology malfunction, instances of low student voting, and guessing on questions, can obviate or minimize the learning engagement benefits of using EVS. Specifically, the use of mathematics questions with low cognitive demand or easy-to-guess answers is seen as being detrimental to enhancing student engagement.

Finally, this research has highlighted that although the behavioural, emotional (and cognitive) engagement constructs have been separately examined, in reality, they are interconnected. Hence, future research will investigate whether the impact of EVS use on engagement, as reported in this study, is stable over time. It would be valuable to conduct a longitudinal study on how (if at all), and the degree to which, the pedagogical alignment of EVS with student learning outcomes catalyses learning beyond the classroom, e.g., in informal and virtual learning contexts.

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