2020

Using Mobile Devices to Facilitate Student Questioning in a Large Undergraduate Science Class

Helen Crompton
Old Dominion University, crompton@odu.edu

Stephen R. Burgin

Declan G. De Paor
Old Dominion University, DDePaor@odu.edu

Kristen Gregory
Old Dominion University, khgregor@odu.edu

Original Publication Citation

Crompton, H., Burgin, S. R., De Paor, D. G., & Gregory, K. (2020). Using mobile devices to facilitate student questioning in a large undergraduate science class. In Management Association, I. (Ed.), *Mobile Devices in Education: Breakthroughs in Research and Practice* (pp. 560-575). IGI Global. https://doi.org/10.4018/978-1-7998-1757-4.ch033

Chapter 33
Using Mobile Devices to Facilitate Student Questioning in a Large Undergraduate Science Class

Helen Crompton
Old Dominion University, USA

Stephen R. Burgin
University of Arkansas, USA

Declan G. De Paor
Old Dominion University, USA

Kristen Gregory
Old Dominion University, USA

ABSTRACT

Asking scientific questions is the first practice of science and engineering listed in the Next Generation Science Standards. However, getting students to ask unsolicited questions in a large class can be difficult. In this qualitative study, undergraduate students sent SMS text messages to the instructor who received them on his mobile phone and via Google Glass. Using observations, coding of texts, and interviews, the researchers investigated the types and level of questions students asked and the perceptions of the instructor and TAs on how the messages were received. From the findings of this study, it is evident that students asked a wide variety of question types and levels. It would appear that important distinctions between voice and text questions are that: (a) a shy or insecure questioner can remain anonymous; (b) questions can be asked in an interactive, but not interruptive manner; (c) there is no time limit to answering questions; and (d) the record of questions on the instructor's phone can be used to guide revision of lecture notes for future semesters.

DOI: 10.4018/978-1-7998-1757-4.ch033

INTRODUCTION

Student questioning is crucial to the learning process. When students pose questions in class, they are more engaged and experience more autonomy (Etkina, 2000; Marbach-Ad & Sokolove, 2000). Asking scientific questions and defining problems are the first practices of science and engineering listed in the Next Generation Science Standards (NGSS, 2013) and the framework that guided their development (NRC, 2012). If asking questions is a core scientific practice, then it stands to reason that encouraging students to engage in questioning within a traditional classroom learning environment is a desirable action on the part of any instructor. Science learning at the early undergraduate level offers a uniquely challenging context for promoting student questioning. In this context, where enrollment in a single course can often be in the hundreds, student-to-student and student-to-teacher communication is uncommon (Cotner, Fall, Wick, Walker & Baepler, 2008). Therefore, the instructor must be skilled in developing techniques to enable students to ask questions in large classes (Cotner et al., 2008; Harper, Etkina & Lin, 2003; Etkina, 2000).

Mobile devices can be used by students to interact with instructors in courses with large enrollments (Caldwell, 2007; Draper & Brown, 2004; Elliot, 2003; Pradhan, Sparano, & Ananth, 2005). The affordances of these communication devices can facilitate various types of interactions, including instructor-to-students, students-to-instructor, and students-to-peers. The purpose of this study is to explore how science students in a large university class used Short Message Service (SMS; which is commonly referred to as text messaging) to ask student generated questions. These questions are explored to determine the topics of questions students ask, such as questions about the organization of the class or questions about science concepts, and the level of those questions (higher or lower level questions). In addition, the researchers examined instructor perceptions of the way questions were received through two different mobile devices; mobile phone and smart glasses. There are various types of smart glasses offered by Sony, Apple, Amazon and Microsoft; however, for this study, Google Glass was used.

The two questions guiding this study are:

1. When students ask questions via text messages in a large classroom, why kind of SMS messages are received?
2. When students ask questions via SMS messaging what sort of questions are asked in terms of higher and lower order thought processes?
3. What are the perceptions of the instructors regarding perceived benefits when receiving student initiated questions using a mobile phone and smart glasses?

LITERATURE REVIEW

The two questions guiding this study focus on four main topics; 1) how student questioning can support learning, 2) higher/lower order questioning, 3) limitations and difficulties in soliciting questions in large classes, and finally 4) how mobile learning can offer an alternative questioning method.

Student Questioning

In the process of becoming a scientifically literate citizen, it is widely argued that the science student should develop an informed understanding of the ways in which knowledge is produced by the scientific community (Shapiro, 2015). The authors of the Next Generation Science Standards (NGSS) advocated for a focus not only on science content, but also on the practices employed by professionals as that content knowledge is constructed (NGSS Lead States, 2013). Among these practices is the asking of scientific questions (NRC, 2012). Indeed, science education research has recently received a renewed focus on the need to better understand and promote student-centered forms of scientifically sound discourse practices in school settings (Kiemer, Gröschner, Pehmer, & Seidel, 2015). Student generated questions are a necessary component of student engagement in scientific argumentation, a highly authentic form of scientific discourse (Chin & Osborne, 2010).

There are many empirically substantiated benefits for students developing and asking questions, including opportunities to: experience autonomy and active learning (Etkina, 2000; Marbach-Ad & Sokolove, 2000); extend comprehension and look at information in different ways (van Zee, Iwasyk, Kurose, Simpson & Wild, 2001); make connections between background knowledge and new information, resulting in a higher level of understanding; activate problem solving strategies to collaborate and resolve conflicts (Chin, Brown & Bruce, 2002); and develop a feeling of enhanced motivation to extend and continue learning (Chin et al., 2002). However, the purpose of a question may simply be to find out what time class will start in next week, to determine the date of the next class test, or to seek a basic definition of a term the instructor just used. Student generated questions are typically lower level questions in that they have not taken a great deal of thought in the development of the question (Almeida, 2012; Chin et al., 2002).

Higher/Lower Order Questioning

Other scholars have studied the level of student questioning in science. Jesus and Moreira (2009) studied three categories from student questions in a chemistry class: (1) the number of questions at the cognitive level, (2) the relationship with the problem, and (3) the orientation to the problem. For the cognitive level, the researchers gave the questions to five professors and 2 PhD students to categorize against Bloom's Taxonomy (1970): knowledge, comprehension, application, analysis, synthesis, and evaluation. Although these use a well-recognized framework, each level of the taxonomy can be interpreted in various ways.

Marbach-Ad and Sokolove (2000a) developed a taxonomy for student generated questions in a higher education science class. These researchers had large classes of 225 students and they focused on students' written questions. Their hierarchical taxonomy, based on Bloom's Taxonomy, for classifying students' questions had eight categories, ranging from lower order questions to higher order questions. The taxonomy was developed empirically in another study by Marbach-Ad and Sokolove (2000b) who asked higher education science students to construct questions after completing the textbook readings. The taxonomy was developed by examining over 150 written questions from a previous class and grouping similar types of questions together. At the lower end of the taxonomy, questions were simple definitions. Depending on the level of questions posed (e.g., low level versus high level questions), students may find themselves engaged in potentially motivating learning that mirrors other practices of science such as the generation of solutions to problems (Chin et al., 2002). Marbach-Ad and Sokolove (2000b) also included a category that was not classed as higher or lower order due to the lack of clarity in what the

student was asking. For example, the question had grammatical or spelling errors that made it illegible. The researchers uncovered benefits to learning beyond ranking students' levels of thinking, such as the benefits for instructors. As students ask questions, opportunities arise for the instructors to assess student learning, provide timely feedback, and assess the quality of students' thinking processes and conceptual understanding. In addition, instructors can identify learning difficulties and adjust instruction to meet student needs (Etkina, 2000; Harper et al., 2003).

Limitations/Difficulties Soliciting Student Question in Large Classes

Lecturing is the most common approach to instruction in higher education (Cuseo, 2007; Mulryan-Kyne 2000) especially when classes are large (Cooper & Robinson, 2000; Cuseo, 2007). This often results in students acting as passive learners (Al-Zahrani, 2015). Passive learning in large classes appears to have a negative impact on student motivation (Wadsworth, Husman, & Duggan, 2007) and attendance (Cooper & Robinson, 2000). Furthermore, despite the large number of students present in one location, students in large classes often report a sense of isolation and anonymity (Svinicki & McKeachie, 2010).

Despite the benefits for both students and instructors, students can be hesitant to ask questions by raising their hand in a large class. Asking questions is a major fear for many students in such settings as it can generate vulnerability (Lattuca & Stark, 2009). Students may fear being considered stupid, or on the flip side, being seen as nerdy; therefore, they often choose more private ways to respond, for example in homework tasks (Etkina, 2000; Harper et al., 2003; Marbach-Ad & Sokolove, 2000). This could be in the form of email, office visits, or conferences before or after class. Such private forms of communication do not necessarily occur in a timely manner. To incite a milieu of student engagement and interaction, students should be encouraged to ask questions (Prince, 2004; Weimer, 2010) and promote opportunities for student questioning (Engle & Conant, 2002). Instructors need to explicitly provide opportunities for students to pose questions (e.g., asking for student questions, fostering environments conducive to such discourse, encouraging small group discussions, planning problem solving activities) if they expect them to do so (van Zee et al., 2001; Chin et al., 2002).

Mobile Technologies

Marx (Vološinov, 1973) and Vygotsky (1929) provided ontological arguments for the use of tools as mediators of society (Marx) and learning (Vygotsky). Vygotsky proffered that tools shape the way people interact with each other and the way people learn. The object used as a tool could well be a digital mobile device that acts as a social mediator in the way that it connects the user with content/learning objects and people. Advancements in mobile technologies are providing more options for learning as these digital tools are smaller, faster, more personalized, and more easily transported than desktop devices. Mobile devices are now recognized as a tool to increase student-instructor interactions (Caldwell, 2007; Draper & Brown, 2004; Elliot, 2003; Pradhan et al., 2005). They allow the interaction between students and instructors to be two-way, rather than the historical instructor-to-student interaction.

Technologies have evolved in the way they integrate with pedagogies. Clickers were an early type of classroom response system where instructors posed simple multiple-choice questions and students gave their responses via handheld remote-control devices to answer multiple choice questions. Such classroom response systems were found to increase student engagement and interaction in response to instructor's questions (Cotner et al., 2008). Web-based programs, such as Socrative and Poll Everywhere offered a

more technologically advanced system where students could participate using their own devices. The instructor still posed the questions, but students now had the opportunity to respond in more ways than just pressing one of four or six buttons. Though relatively technologically advanced, these web-based programs still focus on the instructor-to-student model of initiating interaction.

Text messaging, which is available on both basic and smart phones, is a communication protocol that enables the exchange of short messages between and among individuals without interrupting the effect of real-time conversation. A vast majority of university students are familiar with texting and have been using this technology to interact with peers for many years. Using their own mobile device, students can text message their instructor anonymously as the instructor is unlikely to recognize hundreds of phone numbers. At an appropriate time in the lecture, the instructor can choose to respond to students' texts, clarify information, discuss content, and modify instruction as needed. Text arriving at times that might interrupt the instructors' presentation can be ignored or put on hold. Thomas, Orthober and Schultz (2009) used SMS with students and found that it increased course interactions.

Instructors can receive text message questions via a computer at the lectern, a mobile phone, or a wearable device such as smart glasses. With the portability of wearable technology, this genre of technologies fits as a sub category of mobile devices. Google Glass, the smart glasses used in this study, consists of a head-worn computer mounted in a spectacle frame. A semi-transparent graphical display is projected through a prism so that it hovers in the periphery of the wearer's field of view. Input is achieved by tapping or swiping the frame or by speaking commands, for example "Okay Glass, send a message". There is a video camera, mic, and earpiece. Google Glass can access most web pages and perform other functions, but for the purpose of this study, the smart glasses were only used to receive text messages. Regardless of the instructor's device, during this study the students consistently used text message protocols.

METHOD

Study Context

The initial conceptualization of this project was guided by the course instructor, the fourth author of this report, who reached out to the first two authors, a technology educator and a science educator respectively, to systematically investigate the impact of texting based student questioning in his undergraduate science class. To minimize author bias, the instructor of the course was not involved in the data collection, analysis, or reporting on these sections of the manuscript. An institutional review board reviewed this methodology and confirmed that ethics procedures were in place. Those procedures were followed during this study.

Participants

This study took place in an undergraduate astronomy course at a large Mid-Atlantic public research university. There was a total enrollment of 371 students in this class during the Fall semester and 372 in the Spring semester. The course satisfied a university general education requirement and students were mainly non-science majors. Both sections of the course were equally diverse in terms of gender and ethnicity. Undergraduate enrollment at the university is over 25% African American and over 60%

female. The study was designed to enable the research team to explore the course as a single entity. The student participants, the instructor (a professor of geophysics and astronomy), and the four graduate teaching assistants (TAs) assigned to each course collectively served as a single case that was studied through a descriptive, single case study (Yin, 2015).

Procedures

At the beginning of the 2013 Fall and 2014 Spring semesters, the instructor gave the class his mobile phone number and verbally encouraged students to ask questions during the class time by texting him. He explained that he would receive and respond to messages in real time, however, students were asked not to expect instant answers. Students were reminded of this process throughout the semester. The classes consisted of a 75-minute lecture period with a cyclical process of five to 15-minute lecturettes followed by think-pair-share and in-class student discussions.

Two types of data were collected in this study to answer the research questions. These data were the text messages, interviews with the instructor and TAs. The TAs were present at lectures, each allocated to a section of the large auditorium, and they participated in mentoring classroom activities. During the Fall semester, the instructor received text messages sent to his mobile phone and the instructor would pick up the phone and read the message during class when he heard the notification beep. In the Spring semester, the text messages were also received through the instructor's smart glasses, appearing automatically in the instructor's peripheral view for the instructor to read. The instructor and three TAs were each individually interviewed twice: once regarding their perspectives of students sending text message questions and how they were received via phone and once regarding their perspectives of text questions received via smart glasses.

Student Questions – Text Messages

To determine the characteristics of student generated questions, the two primary researchers began coding using ten a priori codes (Stemler, 2001) developed by Marbach-Ad and Sokolove (2000). These a priori codes were selected for this study as they were being used for the purpose they were developed for, which is to rank student questions based on purpose category and lower or higher order thinking. Two researchers coded data using the a priori codes and then met to discuss inter-rater consistency. From these discussions, the codes were amended and the researchers coded additional data and met again to refine the codes further. Initial discrepancies were discussed and codes were revised until consensus was achieved. This iterative process resulted in the eight final codes displayed in Table 1.

The two primary researchers then independently applied this list of codes to all text messages received in the Fall semester before returning together to discuss their analysis. Using this typological analysis (Hatch, 2002), an individual researcher then coded the remaining questions received via smart glasses in the Spring semester. Typological analysis involves the application of a priori codes based on the literature as a frame for analysis. In this case, the authors relied on a system of codes that was developed from the literature (i.e., Marbach-Ad & Sokolove, 2000; Stemler, 2001) and subsequently modified by the researchers. Note that the lowest-numbered three codes are listed as non-questions and are therefore not included in the higher order and lower order questioning categories.

Table 1. The final set of codes used to analyze the purpose of the student questions

		Codes	Description of the Codes
1		Nonsense	Questions that could not be categorized
2		Information to instructor	Letting the instructor know of something in the class environment
3		Organization of class	Questions related to the structure of the class
4	Lower Order	Definition	Questions asking for a simple definition
5	Lower Order	Explanation	Questions asking for an explanation that went beyond a definition
6	Lower Order	Extension	Questions asking for additional evidence
7	Higher Order	Connections	Questions asking about conceptual relationships
8	Higher Order	Hypothesizing	Questions in which the students generated a hypothesis and asked about its utility

Interviews

The analysis of the interviews followed the principles of coding outlined for use in the application of constructivist grounded theory to reveal themes (Charmaz, 2006). These data were used to answer our second research question. One researcher developed 50 initial codes while analyzing the entire interview data set. Then, two researchers came together to discuss these codes and generated a refined list of focused codes. The researchers then independently used these focused codes to analyze two of the eight interviews. The two raters then discussed any instances of disagreement and refined the application of codes until consensus was reached. An individual researcher then analyzed the remaining interviews accordingly using the refined focused codes. The final 15 codes were categorized into three groups for discussion in the results section: questions, affordances for students, and affordances for instructors. These codes can be found in Figure 1.

RESULTS AND DISCUSSION

In this section, the findings are organized around the major foci of our research questions. The first section provides a response to the first question of this study as to the qualities of student questions. The next section is structured around the second question that focused on instructor perceptions regarding the benefits of receiving student text questions by mobile phone or smart glasses.

Characteristics of the Questions Received from Students via SMS

Findings of the analysis of the SMS text messages of the student generated questions are presented in Table 2. It shows the types of question and the percentages via text and smart glasses. In addition, student questions are provided as examples of questions from SMS to mobile phone and SMS to smart glasses for each of the codes. The first three categories (nonsense, organization, and information) were removed from this table as this was not the major focus of our first research question.

Figure 1. Final interview codes

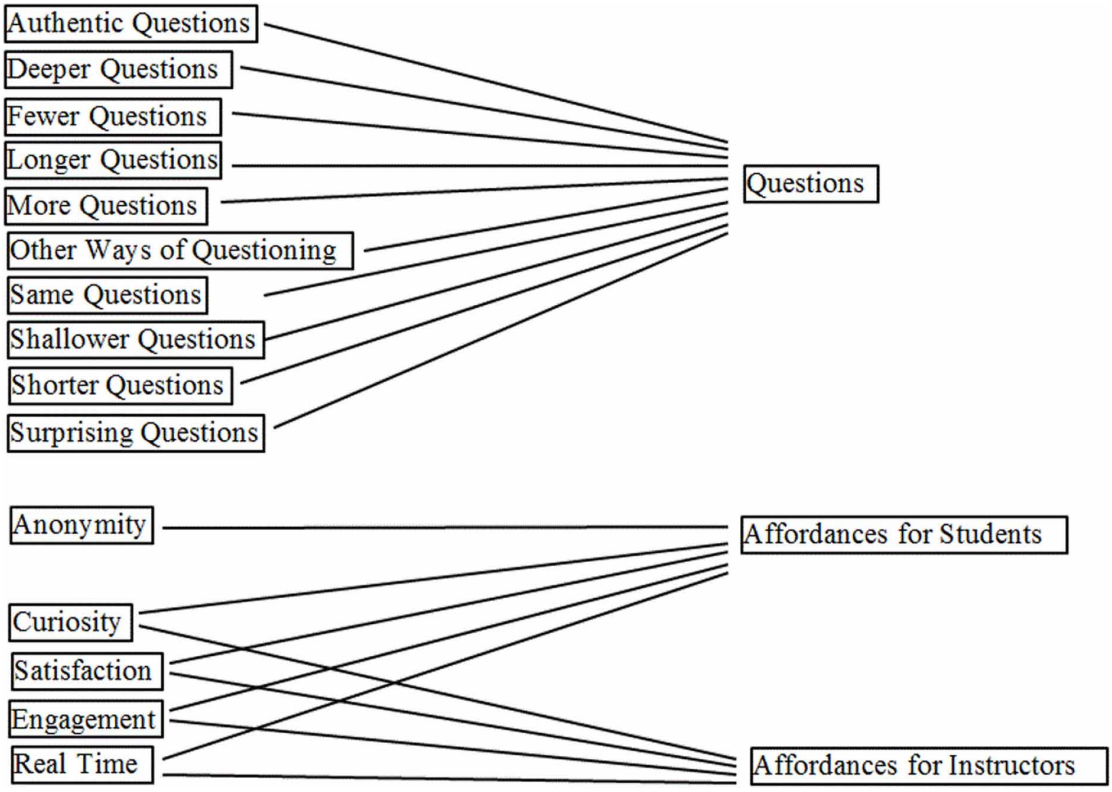

Table 2. Findings from analysis of text message questions received from students

Types of Questions Received	Text-to-Phone	Text-to-Smart Glasses	Examples
Definition	6 = 2%	0 = 0%	*SMS-to-Phone:* What is the heliosphere? *SMS-to-Smart Glasses:* - None available
Explanation	42 = 14%	12 = 21%	*SMS-to-Phone:* What causes sun spots? *SMS-to-Smart Glasses:* What's the theory for the creation of the Moon?
Extension	83 = 28%	17 = 29%	*SMS-to-Phone:* How realistic is terraforming other planets. *SMS-to-Smart Glasses:* Could we ever adapt over time to become dependent on CO2 rather than O2?
Connections	32 = 11%	12 = 21%	*SMS-to-Phone:* Do some solar storms cause the Northern Lights (Southern Lights)? *SMS-to-Smart Glasses:* Is what happened to the moon the same thing that happens to Mars...the bending of light through atmosphere?
Hypothesizing	4 = 1%	2 = 3%	*SMS-to-Phone:* Are cacti a good source for terraforming in Mars because of their ability to hold in water? Or would it freeze inside of them? *SMS-to-Smart Glasses:* Could we create some type of greenhouse effect on mars effective enough to warm the atmosphere significantly?

It is clear from these data that the "explanation" and "connections" questions increased in relative frequency upon the introduction of smart glasses. In both cases, the frequency of the highest level of questions, "hypothesizing", was relatively low. The instructor had been using text messages in previous classes; however, as this class was being studied, he may have been more aware of the purpose and level of questions he was receiving.

From the results in Table 2, there is evidence that students are using text messages to ask questions about science, some of which went far beyond asking for a simple definition or explanation. This aligns to the call from scholars, governments, and organizations (e.g., AAAS, 1993; Chin & Osborne, 2010; NGSS Lead States, 2013) for students to become involved in scientifically sound discourse practices to become scientifically literate citizens. Furthermore, students who asked questions may gain from benefits such as the experience of autonomy and active learning (Etkina, 2000; Marbach-Ad & Sokolove, 2000), and the opportunities to make connections, resolve conflicts, and activate problem solving strategies (Chin et al., 2002; Gallas, 1995).

In the analysis of the level (higher/lower order) of questions asked, Table 3 displays the percentage of questions at each level. There appears to be a good representation of communications across all three categories (higher order, lower order, and non-questions) with the text messages to the mobile phone. The text questions to smart glasses display a higher number of higher order questions (53%) than the other categories, although the remaining percentage is spread across the other two categories.

The students used the text to smart glasses to ask a number of higher order questions. It would appear that the technological tools provided an opportunity for students to ask advanced questions. This positively influenced the learning of the student asking the question as well as others in the class. Furthermore, the students who asked those questions were acting in accordance with the NGSS standards in asking scientific questions and engaged in this as a scientific practice.

In reviewing the results on the percentage of hypothesizing questions, the results were low for both semesters. This low number may be due to the difficulty in constructing such questions and the academic level of the students in the class. In a review of the number of words and the length of the different questions, hypothesizing questions were typically longer than others. As data were triangulated using the observations, it was recorded that the instructor made negative comments in both semesters about scrolling through long messages on the mobile phone and the difficulty of reading them on smart glasses. On smart glasses, the font size decreases incrementally with increasing message length, making long messages progressively more difficult to read. When using the mobile phone, the font size remained constant but the instructor had to scroll to see more of the message. These comments may have inadvertently added to the lack of hypothesizing questions asked by the students.

Table 3. Percentages of levels of questions

Level of Questions	Text-to-Phone	Text-to-Smart Glasses
Higher Order Questions	40%	53%
Lower Order Questions (including questions about the organization of the class)	30%	28%
Non-Questions	30%	19%

Note: percentages do not total 100% due to rounding to the nearest integer.

The spread across the levels of questioning is interesting as it appears that students are using text messages to ask lower order questions just as much as other categories. Watts et al. (1997) described a feeling of vulnerability that students can sense as they raise their hands to ask questions due to a fear of developing negative impressions. A large part of that negativity is from students concerned about asking "stupid" questions (Etkina, 2000; Harper et al., 2003). From the results of this study, it would appear that students do not have this concern when asking questions using text messages in this large class. 30% of questions received to the mobile phone and 28% to smart glasses were lower order. Only a small number were asked at the definition level with 2% to phone and 0% to smart glasses. Questions about the organization of the class also fit into the lower order category and students appeared comfortable asking these via text. These may have been questions previously avoided by students.

The greatest difference in students raising their hands versus using text messages to ask questions is anonymity. When a student raises their hand and verbally asks a question, the rest of the class knows who asked the question and would also be able to hear that student verbally construct the sentence in real-time. As the student uses text messages, they have the question answered but they remain anonymous to the rest of the class. This perhaps resulted in an increase of questions of lower levels (regardless of the type of mobile technologies used) due to the students' perceptions that others would not mock their naïve wonderings due to not knowing who it was that asked the question. One would expect that the potential for embarrassment would limit the number of lower level questions apart from these mobile technologies when traditional lecture formats require students to raise their hands and then ask a question with the eyes of the entire auditorium upon them.

There is also the added benefit of using texts in that the student can construct their sentences and then go back to read and check for meaning and error before they send them to the instructor. It could be argued that educators prefer students to ask higher order questions rather than lower order. However, providing students the opportunity to ask lower order questions is crucial as they may be missing a small, yet very important, understanding that underpins higher order concepts; for example, the student may not understand the meaning of a term. Without the opportunity to gain such basic underpinning information, students arguably cannot move on to more important concepts and questions.

Instructor and TA Perspectives

Interviews with the instructor and course TAs offered valuable insights into their perspectives on the use of these mobile technologies in class. The instructor described the value he placed on student questioning and how it allowed him to monitor engagement and check students' thought processes. The interview data were coded and organized into three categories that were employed in structuring this section of the manuscript. Those three categories are questions, affordances for students, and affordances for the instructor. The latter two appear positive as that was the overall message from the synthesis of the information and the codes. Nonetheless, negative points were discussed, and these are also described in these sections.

Questions

There were many positive descriptions of the questions in the interviews, hence the inclusion of codes such as authentic questions and deeper questions. In one interview, the instructor described the "interesting" questions he had received. "Last class a student asked me, 'Why don't black holes have a temperature?

To me, that's just really thinking." In other words, there is a value to students asking questions in large undergraduate science classes as it fosters a depth to their thinking. In the second interview following the transition to texting to smart glasses, the instructor thought students were asking higher order questions at a more advanced level than those in the first semester. "My gut feeling is that the questions were more well-formed [than those from the text to phone] and thoughtful…I felt there were fewer silly questions."

The TAs seemed to agree. One in particular, described these questions as being "real" and "relevant" when asked by students through text message technology. When analyzing interviews of participants in which they discussed the real-time nature of questions, these were often coded as "authentic questions" because the questions were closer to the topic at hand. The data from the analysis of the text messages show that students asked more lower order questions when the text went to smart glasses than when it was received via a mobile phone. Nonetheless, there were fewer nonsense questions and information to the instructor in the smart glasses semester.

There also was a description by the instructor of what we have coded as "shallower questions" that may have been a product of the anonymity afforded by the mobile technologies. The instructor told us, "the questions I get on texts are much more naïve, and like I said, they are unashamed and unafraid to ask, unafraid to look stupid in front of their peers… which I think is a factor."

Interestingly, one TA in particular thought that the questions were both more frequent and potentially deeper when received via smart glasses. "They are questioning more so maybe the questions get a little bit more deeper [sic]." The instructor did think that higher level questions might have resulted from student curiosity with the new technologies. "It may be a novelty, you know, a first-time effect or something." However, the instructor actually thought that he received fewer questions overall after implementing smart glasses.

Affordances for Students

As the coding was conducted, a trend towards affordances for students emerged from the interviews for text messages to phone and smart glasses. In the initial interview, the instructor describes how he believed that student engagement had increased since he had been encouraging students to use their mobile phones. This came out in how he suggested that the use of text-messages questioning forced him to focus on engagement due to the questions that he was receiving. He said, "Okay, well… I think student texting keeps me honest because it prevents me from, you know, assuming that the students are listening, understanding, engaged, etc. So it makes me work harder to keep them engaged."

In the analysis of the texts, the results appeared to show that students utilized the availability of the technology to engage in asking higher order scientific questions as well as the anonymity of the text message process to ask lower order questions. The interview comments of the instructor and the TAs concur with this finding. In the initial interview, the instructor discussed how text messages allowed for more naïve questions than were previously asked. Comments from the TAs also described the positive affordance of the anonymity. One TA stated in the initial interview, "Maybe some of them don't want to raise their hand and get humiliated… It's more discreet if they just text."

Affordances for Instructors

The benefit for the instructors, particularly when using smart glasses, was a theme that emerged from our interview analysis. During the interview both the instructor and the TAs discussed the benefits of

"real-time" that were afforded by smart glasses. SMS messages received by phone caused the instructor to take breaks in his lecture to check his mobile phone and screen the questions he was receiving to decide which ones(s) to answer. One TA described the real-time benefit as he was interviewed in the second semester "[When using text to phone] someone has a question… and it gets to him and he's four slides ahead when he remembers to check questions." This could be frustrating to students as the instructor moves ahead with the lecture and their question goes unanswered until he notices. With smart glasses, the TA stated, "He gets questions real-time now and he doesn't have to walk around with his phone all the time." In the instructor interview, the instructor described how he had perceived a similar negativity towards text-to-phone when he was able to compare his actions to how he received texts with smart glasses. Before smart glasses, questions were "three or four slides back… and with Glass… [they] seemed to be closer to the topic, the current topic."

When the instructor used smart glasses, the messages appeared in the top right of his semi-transparent, eye-level screen. Therefore, there was no need to do any further action than read the text that appeared in his field of vision at the same time as he was also looking at the students. This is a good example of how wearable technologies are a potentially effective way for an instructor of a large course to receive text messages from students that are closer to the topic at hand. The instructor did state how it would be even more beneficial if the instructor could easily forward a question to his or her slide presentation for all to see, without showing the questioner's phone number. This is a further enhancement to these technologies that may appear in the future.

Study Limitations and Future Studies

A limitation of this study is that it only provides a snapshot of one class. As a result, we do not want to overemphasize the differences in the types of questions received via the two different methods (phone vs. Google Glass). That said, the interviews with the instructor and the course TAs offers some thoughts regarding the merits of each method from their perspectives. It would be beneficial for future studies to collect further data to determine the consistency of these findings. In addition, in this study the researchers gathered less data from SMS to smart glasses. It would have been beneficial to this study if further data could have been gathered. This study provides ideas of the potential of wearable technologies, such as smart glasses. It will be interesting to see how the second generation of Google Glass will compare to the first generation used in this study. Other similar wearable technologies, such as Microsoft HoloLens may offer further benefits to the instructor. Future studies could also compare student generated questions with and without technologies.

CONCLUSION

Marbach-Ad and Sokolove (2000) postulated that large science courses could be designed in ways that foster student questioning, a desirable practice in science and a key part of authentic scientific discourse. The results of this research indicate that mobile technologies can have a part to play in designing engaging lessons and can provide a specific way to enhance students-instructor interaction during a large undergraduate science class. From the findings of this study, it is evident that students asked a wide variety of questions pertinent to science. These questions are both higher order and lower order questions. The technology allowed students to ask pertinent real-time higher order questions to extend their

understandings and engage in scientific discussions. Another important finding was that students were asking lower order questions, and an argument has been made that this is due to the anonymity provided by the technology. Students are then gaining an understanding that may have been obstructed before as they did not have that underpinning knowledge. Students were asking higher level questions to even hypothesize with the new information they had gathered.

It would appear that an important distinction between voice and text questions is that: (a) a shy or insecure questioner can remain anonymous; (b) questions can be asked in an interactive but not interruptive manner - the instructor can respond to simple requests such as "please go back a slide" without announcing that he is doing so in response to a request; (c) there is no time limit - with raising-hand questions, instructors may not wait long enough for a student to develop the courage to raise their hand or may decide to answer, say, three questions and then announce that it's time to move on; and (d) the record of questions on the instructor's phone can be used to guide revision of lecture notes for future semesters.

Hands-free wearable technology constitutes a new sub-category of mobile devices that is predicted to see rapid growth in the near future. It is not certain whether the specific instance of Google Glass will outlast the development phase, given its cult reputation and high cost; however, pending devices such as the Apple iWatch and Microsoft HoloLens, will ensure that wearables remain a frontier for technological exploration and innovation. This research study adds to the empirical literature base regarding how an instructor could utilize mobile technologies to encourage student questioning during large undergraduate lectures, something that is of benefit within the discipline of science.

REFERENCES

Al-Zahrani, A. M. (2015). From passive to active: The impact of the flipped classroom through social learning platforms on higher education students creative thinking. *British Journal of Educational Technology*, *46*(6), 1133–1148. doi:10.1111/bjet.12353

Almeida, P. A. (2012). Can I ask a question? The importance of classroom questioning. *Procedia: Social and Behavioral Sciences*, *31*, 634–638. doi:10.1016/j.sbspro.2011.12.116

American Association for the Advancement of Science. (AAAS). (1993). Benchmarks for science literacy: Project 2061. New York: Oxford University Press.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1970). *Taxonomy of educational objectives: The classification of educational goals (Handbook 1: Cognitive domain)*. New York: David Mckay.

Caldwell, J. E. (2007). Clickers in the large classroom: Current research and best practice tips. *CBE Life Sciences Education*, *6*(1), 9–20. doi:10.1187/cbe.06-12-0205 PMID:17339389

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. London: SAGE.

Chin, C., Brown, D. E., & Bruce, B. C. (2002). Student-generated questions: A meaningful aspect of learning in science. *International Journal of Science Education*, *24*(5), 521–549. doi:10.1080/09500690110095249

Chin, C., & Osborne, J. (2010). Supporting argumentation through students' questions: Case studies in science classrooms. *Journal of the Learning Sciences*, *19*(2), 230–284. doi:10.1080/10508400903530036

Cooper, J., & Robinson, P. (2000). The argument for making large classes seem small. In J. MacGregor, J. Cooper, K. Smith, & P. Robinson (Eds.), *Strategies for energizing large classes: From small groups to learning communities* (pp. 5–16). San Francisco: Jossey-Bass. doi:10.1002/tl.8101

Cotner, S. H., Fall, B. A., Wick, S. M., Walker, J. D., & Baepler, P. M. (2008). Rapid feedback assessment methods: Can we improve engagement and preparation for exams in large-enrollment courses? *Journal of Science Education and Technology*, *17*(5), 437–443. doi:10.100710956-008-9112-8

Cuseo, J. (2007). The empirical case against large class size: Adverse effects on the teaching, learning, and retention of first-year students. *Journal of Faculty Development*, *21*(1), 5–21.

Draper, S. W., & Brown, M. I. (2004). Increasing interactivity in lectures using an electronic voting system. *Journal of Computer Assisted Learning*, *20*(2), 81–94. doi:10.1111/j.1365-2729.2004.00074.x

Elliot, C. (2003). Using personal response system in economics teaching. *International Review of Economics Education*, *1*(1), 80–86. doi:10.1016/S1477-3880(15)30213-9

Engle, R. A., & Conant, F. C. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners' classroom. *Cognition and Instruction*, *20*(4), 399–483. doi:10.1207/S1532690XCI2004_1

Etkina, E. (2000). Weekly reports: A two way feedback tool. *Science Education*, *84*(5), 594–605. doi:10.1002/1098-237X(200009)84:5<594::AID-SCE3>3.0.CO;2-U

Gallas, K. (1995). *Talking in their way into science: Hearing children's question and theories, responding with curricula*. London: Teachers College Press.

Harper, K., Etkina, E., & Lin, Y. (2003). Encouraging and analyzing student questions in a large physics course: Meaningful patterns for instructors. *Journal of Research in Science Teaching*, *40*(8), 779–791. doi:10.1002/tea.10111

Hatch, J. A. (2002). *Doing qualitative research in education settings*. Albany: State University of New York Press.

Jesus, H. P. D., & Moreira, A. C. (2009). The role of students' questions in aligning teaching, learning and assessment: A case study from undergraduate sciences. *Assessment & Evaluation in Higher Education*, *34*(2), 193–208. doi:10.1080/02602930801955952

Kiemer, K., Gröschner, A., Pehmer, A. K., & Seidel, T. (2015). Effects of a classroom discourse intervention on teachers practice and students' motivation to learn mathematics and science. *Learning and Instruction*, *35*, 94–103. doi:10.1016/j.learninstruc.2014.10.003

Lattuca, L. R., & Stark, J. S. (2009). *Shaping the college curriculum: Academic plans in context* (2nd ed.). San Francisco, CA: Jossey-Bass.

Marbach-Ad, G., & Sokolove, P. (2000a). Can undergraduate biology students learn to ask higher level questions? *Journal of Research in Science Teaching*, *37*(8), 854–870. doi:10.1002/1098-2736(200010)37:8<854::AID-TEA6>3.0.CO;2-5

Marbach-Ad, G., & Sokolove, P. (2000b). Good Science Begins with Good Questions: Answering the Need for High-Level Questions in Science. *Journal of College Science Teaching*, *30*(3), 192–195.

Mulryan-Kyne, C. (2010). Teaching large classes at college and university levels: Challenges and opportunities. *Teaching in Higher Education*, *15*(2), 175–185. doi:10.1080/13562511003620001

National Research Council. (NRC). (2012). A framework for K-12 science education: Practices, cross-cutting concepts, and core ideas. Washington, DC: National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: National Academies Press.

Pradhan, A., Sparano, D., & Ananth, C. V. (2005). The influence of an audience response system on knowledge retention: An application to resident education. *American Journal of Obstetrics and Gynecology*, *193*(5), 1827–1830. doi:10.1016/j.ajog.2005.07.075 PMID:16260243

Prince, M. (2004). Does active learning work? A review of the research. *The Journal of Engineering Education*, *93*(3), 223–231. doi:10.1002/j.2168-9830.2004.tb00809.x

Shapiro, B. (2015). Questioning for teaching and learning in science. In *Encyclopedia of Science Education* (pp. 815–817). Springer Netherlands.

Stemler, S. (2001). An overview of content analysis. *Practical Assessment, Research & Evaluation*, *7*(17). Retrieved from http://PAREonline.net/getvn.asp?v=7&n=17

Svinicki, M., & McKeachie, W. (2010). *McKeachie's teaching tips: Strategies, research and theory for college and university teachers* (13th ed.). Belmont, CA: Cengage Learning Inc.

Thomas, K., Orthober, T. K., & Schultz, N. (2009). Using Text-Messaging in the Secondary Classroom. In I. Gibson, R. Weber, K. McFerrin, R. Carlsen & D. Willis (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2009* (pp. 2159-2164). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

van Zee, E., Iwasyk, M., Kurose, A., Simpson, D., & Wild, J. (2001). Student and teacher questioning during conversations about science. *Journal of Research in Science Teaching*, *38*(2), 159–190. doi:10.1002/1098-2736(200102)38:2<159::AID-TEA1002>3.0.CO;2-J

Vološinov, V. N. (1973). *Marxism and the Philosophy of Language*. Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (1929). The problem of the cultural development of the child II. *The Journal of Genetic Psychology*, *36*, 415–432.

Watts, M., Gould, G., & Alsop, S. (1997). Questions of understanding: Categorizing pupils' questions in science. *The School Science Review*, *79*(286), 57–63.

Weimer, M. (2010). Taking stock of what faculty know about learning. In C. Christiensen Hughes & J. Mighty (Eds.), *Taking stock: Research on teaching and learning in higher education* (pp. 81–93). Montreal, Kingston: McGill-Queen's University Press.

Yin, R. K. (2015). *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: Sage.

This research was previously published in the International Journal of Mobile and Blended Learning (IJMBL), 10(1); edited by David Parsons and Kathryn Mac Callum; pages 48-61, copyright year 2018 by IGI Publishing (an imprint of IGI Global).