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ARTICLE

Digital Voting Systems and Communication in Classroom Lectures

- *an empirical study based around physics teaching at bachelor level at two Danish universities*

Helle Mathiasen*

Studies on the use of digital voting systems in large group teaching situations have often focused on the "non-anonymity" and control and testing functions that the technology provides. There has also been some interest in how students might use their votes tactically to gain "credits". By focusing on an empirical study of students' experiences with digital voting systems in lectures at two Danish universities, this study considers the premises and the contexts surrounding this technology. It will also aim to show that for both instructors and students, digital voting systems are a much broader resource than simply a device for facilitating "non-anonymity", test, control and allocation of credits. The case studies showed, for instance, that digital voting systems can be conducive to a more open approach in which the systems are used as communication tools and teaching resources in situations where feedback is important, as well as to the more widely recognized controlled approach.

According to the students, digital voting systems do present the instructors with challenges. Some of these are discussed along with the students' suggestions for further development of digital voting systems' usage in lessons. The overall hope is that this case-based Danish perspective, which is viewed through a systems theory lens, can contribute to the pedagogical discussion surrounding the use of digital voting systems and provide a springboard for further research in this area.

Keywords: teaching; communication; digital voting systems; learning

Introduction

In this study we use systems theory to analyze the concept of communication in relation to digital voting systems in educational settings. There are already a wide variety of digital voting systems in use in today's classrooms and lecture halls. These range from straightforward button-press systems where users are given a device with six buttons that they can press, as instructed, to vote on possible answers. Other devices resemble mobile phones with their small monitors and keyboards. Users of these systems can write their responses in text and numbers. In both these instances there is a second part of the system, which is used by the instructor – this is essentially a computer that can receive the data from the students' hand held devices. Often the instructor will also have a screen to display questions, and tabulate and display student responses. An alternative to dedicated digital voting systems is for students to use mobile phones to cast their votes, while net-based freeware provides an instructor-student interface.

* University of Copenhagen, Denmark
helle.mathiasen@ind.ku.dk

In addition to the variety in digital voting system configuration, there is also a wide range of terms used to describe these systems: Electronic Voting Systems, Audience Paced Feedback, Classroom Communication, Student Response Systems, Audience Response Systems, voting-machines, zappers, clickers and Classrooms Response Systems. Such systems are increasingly finding a place in higher education and have proved especially popular with university lecturers in the sciences. (e.g. Barber *& Njus* 2007; Bode *et al.* 2009; Bruff, 2011; Caldwell, 2007; Fies& Marchall 2006; MacArthur *&* Jones 2008; Mazur, 1997; Mazur *&* Crouch, 2001; Stav *et al.,* 2010).

To find out more about the impact of digital voting systems in higher education, this paper will address the topic from the viewpoint of an empirical study that is based around physics teaching at bachelor level at two Danish universities. By bringing together and discussing some of the empirical findings that have emerged, the intention is to shed more light upon the contexts in which digital voting systems are used, and in particular, to show how both students and instructors are using the devices as more than a "voting-machine".

The paper's empirical portion is based on data obtained via observations of teaching, group interviews and follow up interviews with the instructors. The findings are

intended to serve as a starting point for the on going discussion about which technology best facilitates teaching and learning, and what should be the overriding pedagogical considerations.

The theoretical foundation

This study uses systems theory - the idea that systems are operationally closed and self-referential (e.g. Luhmann, 1995) – as the basis for its analysis of digital voting systems' usage. For the purposes of this article both psychic systems (operating mode: conscious activities) as well as social systems (operating mode: communicative activities) were considered. The systems are conceptualised as being operationally closed to each other, but can mutually impact one another through "structural coupling". This means, among other things, that learning is observed as knowledge construction (psychic systems) and that teaching is viewed as a unique and specialized form of communication (social systems). In this theoretical framework, the learner (students as well as teachers) is observed as a psychic system, and this system operates in and maintains itself by means of conscious activities. These systems are operationally closed but there is potential for structural coupling. You cannot predict what is going to happen during a classroom lecture, for example, even if it has been planned and organized down to the last communicative detail. This approach implies a view of systems as non-deterministic, which will be further explained in the following presentation of concepts relating to trivial and non-trivial systems.

Communication – what can be observed?

The communication concept departs from earlier transfer models (e.g. Shannon, 1949/1971) by defining a *communication unit* as a synthesis of *three* selections, where the first two selections, namely the information to be sent and the message form, the utterance, are chosen by the "mediator", or "utterer", whilst the third selection, the interpretation or choice of understanding is an activity that is undertaken by the "addressee". (Luhmann, 1992)

The first two selections in a communication unit use language (in the broadest sense). The communicated information (the first two selections) can be observed, but the third selection, choice of understanding, cannot be observed (a conscious activity).

Only after the addressee has received and chosen an interpretation for the communicated information, then acted upon this with the addressee's chosen communicated information (reply), can we observe and interpret what the addressee may have understood. With this understanding of what communication entails, it is easy to see why there needs to be at least a chain of two communication units, before we can begin to talk about feedback.

This perspective illustrates how the mere act of "sending" information does not in itself constitute communication. When viewing digital voting systems in teaching situations from this perspective, it becomes clear that the singular act of presenting a digital voting system question does not constitute a whole communication unit. Only after an addressee (student) focuses on the question being asked and then chooses an interpretation, can we speak about a full communication unit. A follow up voting response is, therefore, a new communication unit, composed of the first two selections (information to be sent and message form) and the third selection, which is the choice of understanding – essentially the pre-programmed choices linked to the buttons or key presses.

What determines the effectiveness of digital voting systems, as a learning tool, is the degree to which the instructor focuses on the voting result, and so can choose *their* understanding. The instructor has in a sense, the ball in their court. They are the primary agent when it comes to the continuation of the communication and indeed the continued feedback option that is given to the students. This causes reflection on the nature of teaching, which is briefly addressed in the next section.

The concept of teaching

Teaching can be defined as that special form of communication, whose underlying intention is to effect change. In this context the communication has as its core an intentional propensity to "irritate", to "give sustenance" or to bring about "perturbation". It is the engineered context that brings about the possibility for the activation/ continuation of learning processes, hence knowledge construction.

Particularly salient in this context, is the fact that the students can teach themselves. Consequently, it is relevant to consider the spectrum of possible communicative contexts that make this possible. One notable feature is that the students perceive the world through their own particular lens, which has an impact on their understanding of the environment based on observations and related knowledge constructions. This makes every person a "unique system", teachers as well as students.

Choice of communicative understanding is thereby always system-specific, in the sense that it is always constructed through self-generated processes and therefore a teaching session can theoretically produce just as many self-referential understandings among students as there are students present.

This systems theoretical interpretation of communication and learning as continuous knowledge construction has implications for the way that we think about teaching. It not only informs a perspective that elevates the importance of "irritating" participants in class (students), as they represent closed self-referential systems needing to be opened to new meanings, it also recognises the fact that this intended "irritation" or "disturbance" of the students, does not have any predefined simple or best practice solution.

The systems theoretical perspective also lends itself to the identification of strategies that could be used in the development of a better teaching environment since communication is at its core. At the same time, the theory's acknowledgement that the world is complex provides the perspective that "Complexity means being forced to select; being forced to select means contingency; and contingency means risk." (Luhmann, 1995 p. 25)

Maintaining a focus on communication is beneficial when considering how digital voting systems can provide useful support to feedback activities and insight into

student and instructor thinking. Both the communication between students, as well as the communication that takes place between the instructor and students, play a crucial role in supporting student learning.

The connection between teaching and learning

The use of a systems theory perspective is not only helpful when considering the communication aspects of digital voting systems, but it also offers the opportunity to consider scenarios in terms of trivial and non-trivial machines or systems (Foerster and Pørksen, 2003), and this could throw light on the coupling between teaching and learning and the complexity of systems. Trivial systems are systems that, when given a certain input, will generate a predictable output (Foerster & Pörksen 2003). In other words, trivial systems are systems that are programmed to handle input according to context, output is always dependable, contingent on the causal system and therefore there is a direct relationship between input and output. Non-trivial systems, are in contrast, self-referential systems, which operate from their given condition and concrete context. They are not dependable, nor are they causally contingent.

It is widely recognised that although one might hope that the educational system could function as a trivial system with respect to generating desired outputs, and so provide a certain level of security in those outputs (Foerster & Pörksen 2003), this perspective does not allow for complexity. Trivial systems primed to generate determined output when fed with appropriate input do, however, exist and in certain circumstances also work (Foerster 1993 in Luhmann 2006).

But educational systems are non-trivial systems and according to systems theory, non-trivial systems are dependent upon context. This doesn't mean that they cannot become trivialised, but from a systems theory perspective teaching *per se* cannot generate purely causal effects. In fact, perceiving teaching systems in this way- as non-trivial systems, necessarily demands that pedagogic choices are made through human involvement. Furthermore, this view entails, due to the complex nature of systems, a need for skilful management of contingencies and risk.

The communication inherent in any teaching situation where there is a possibility for continuous control of understanding can be seen as having potential for nurturing further communication and continued knowledge construction, but there is no guarantee that the understanding that is achieved is actually what was intended.

Case study

The following case studies carried out at two Danish universities exemplify the use of digital voting systems in Danish university settings. The following description of the empirical field of research serves as a frame for discussions pertaining to the findings from the case studies.

Empirical study

The first observations of lecture teaching involved between 20–43 students. Group interviews with six students at a time were held immediately after the classroom teaching. All the students volunteered, no specific criteria were requested for participation in the group interviews. Instructors were interviewed separately, primarily to ensure reliability of the teaching settings and to give the instructors the possibility to express their reflections on the observations presented to them by the researcher. The instructors' reflections will not form part of the discussion in this paper, but provide verification of the settings used for the research observations.

The questionnaire was designed in an open question format and focused on the students' approaches to digital voting systems' usage and learning potential, motivation, anonymity, collaboration, and student ability.

The empirical analysis is presented in different formats. First, short descriptions of digital voting systems' usage are presented, and thereafter, we look at the settings in which the digital voting systems are used. The outcome of the group interviews is presented next, along with additional material for clarification, which was taken from the conversations with the instructors. The theoretical perspective is connected to this part of the presentation, and provides an interpretive frame for understanding digital voting systems' usage in instructional settings. The observations are presented in order to provide a concise picture of the actualized communication in the specific settings.

Observations of classroom lectures

Observation 1: Lecture in the time period 8am-11am; 43 bachelor students; traditional table arrangement in rows

The instructor used the teaching functionality provided by the digital voting system to present three questions to the students at the commencement of the lesson. Each question had 3 to 5 voting options, and these were given as an appetizer to new material to be introduced during the lesson. The questions were designed to provide intuitive answers. At the end of the lesson eight more digital voting system questions were posed, and these served as a review strategy for comprehension and retention of the material presented during the lecture. These questions had four or five response possibilities.

The instructor showed the voting summaries as graphic elements on a digital board and also encouraged discussion among pairs of students in the class. Viewpoints and considerations were expressed about the questions that prompted intuitive responses, but there was less discussion surrounding the eight review questions.

The instructor went through the relevant theory after each vote. Only a few students had their computers on, as most of them were busy listening and taking notes. Digital voting systems were set to "anonymous mode".

Observation 2: Lecture in the time period 1pm-4pm; 20 bachelor students, traditional table arrangement in rows

The first questions to be answered using the digital voting system addressed the theme of the previous lecture. Later in the observed lecture the students were asked to vote on a further ten questions that related to the material introduced during the lecture. At the end of the lecture there were even more questions to be answered

using the digital voting system and these included ten evaluation questions and some teasers for the next lecture. In each voting instance the students were given between three and five possible responses. In this lecture situation the instructor asked the students to first answer the digital voting system's questions individually. The voting summaries were shown on a digital board. When there was no consensus in the answers, the instructor asked the students to discuss the results in pairs. Then the instructor asked the students to vote again. If the students managed to answer most of the questions correctly then the instructor's explanations were short. Often, the instructor asked a student to explain why the chosen answers were correct. In this session the students' attention was mainly directed towards the communication from the instructor. None of the students used their computers. The digital voting systems were set to "non-anonymous mode".

Answer status after the observations

In observation 1, approximately 25% of the students expressed their answers by putting their hands up, whilst in observation 2, this percentage is seen to be considerably higher at 50%. There was an average click through voting rate of 75% and almost 100% for the two respective observations. Most of the oral responses were answers to the instructor's questions. Only a few of the students asked the instructor questions.

The instructor in Observation 2 chose to run the experiment with the digital voting systems in "non-anonymous mode" as he wished to give formative feedback to the students and to support them in their academic development. It was also his intent to collect statistics for evaluation purposes.

After this brief description of settings we will turn to the group interviews with students and point out the essential findings.

Group interview with the students

The students' experience with digital voting systems has been largely gained in the context of classroom lectures. Below is a summary of the interviewed students' opinions about the use of digital voting systems in classroom lectures:

Digital voting systems use – a pedagogical challenge

The students believed:

- That the instructor's pedagogical and didactic approach is highly relevant
- Digital voting systems could be useful in many academic contexts
- Digital voting systems should be integrated into the lessons as long as there is variation of use both within lectures and also between lectures that form part of a complete course or module.
- Digital voting systems are shown to enhance confidence and motivation levels and to have a positive impact on the degree of activity among students (impacting their incentive to participate)

There was general agreement that teaching should be able to embrace academic and pedagogical differences and that it should support students with diverse prerequisites, potential and preferences. The students' thoughts on digital voting systems were considered through the lens of systems theory (as outlined above), and with this insight it was noted that: the students expressed a clear wish that the instructor should think in terms of non-trivial systems and that the teaching should not be driven by a tendency to trivialize the teaching or the participants therein.

Feedback is more than a click

There was a general consensus among students that digital voting systems provided value in a teaching setting. Their affective benefits for attaining academic knowledge could be directly linked to teaching practice as they allowed for increased and useful feedback and reflection for both the students and the instructor.

Digital voting systems can offer the following kinds of feedback and assessment possibilities:

- Polling result (providing information for the instructor and students but without any follow up from the instructor)
- Individual responses to digital voting systems' questions without dialogue with peers
- Individual answers to digital voting systems' questions after dialogue with peers
- Polling result and subsequent exploration of the material with the instructor or students
- Polling result and follow up with individual advice

The first option, which in a systems theory perspective could be called simple feedback, was something that the students did see as an option, however, the students pointed out that it was important that everyone had answered correctly:

> It reduces the quality of the teaching if digital voting systems are used for clicking answers and that's it. It is the arguing, one with another, that is good.

In fact all the options listed can be seen as a wish from the students for communication not to be trivialized by the introduction of digital voting systems. Instead the students wanted the systems to be used to test their own understanding via communication. The key word is communication when it comes to reflections about learning and more specifically, knowledge construction.

Digital voting systems should support the teaching rhythm

Each voting session should not last too long "for then the teaching is stalled, and one begins to think of other things." Some students however, did think that they had too short a time to be able to reflect, and this could result in guessing as opposed to voting thoughtfully. The students were in agreement that "they were kept motivated". They also thought that the optimum usage of digital voting systems

was when two sets of no more than six questions were presented during a lecture. The time aspect was planned in connection with activities that were informed by the voting. The students preferred to have a debriefing and discussion immediately after the voting.

> "If you wait until next time, then you forget the question, as well as your own arguments and the arguments that were proposed by others".

The time factor does enter the equation as a significant parameter, with regard to the continual processing of communication and learning.

Questions are more than simple multiple-choice questions

The students were in agreement that it was important to alternate between the following types of questions:

- Factual questions
- Repetition questions
- Questions designed for intuitive responses
- Questions designed to invite discussion
- Appetizer questions

The students' experience with digital voting systems was that this kind of technology could provide "a more intuitive understanding of the theoretical material", and that it required that the instructor have an understanding of the various possibilities open to them. Not all instructors were good at formulating questions for digital voting systems and similarly, not all were good at following up with communication about their questions. The students thought that this was related to the different teaching competences of various instructors. The students also agreed that not all instructors had reflected in sufficient degree over their use of digital voting systems in the class and they gave examples of instructors who were good at their job and who could use digital voting systems advantageously whilst instructors who were not so good, in their eyes, could not become better instructors simply by using digital voting systems. The students agreed with the following statement made by one of their peers: "university instructors are in need of pedagogical skills", but it should be mentioned, that the instructors who took part in the two case studies were actually praised by the students.

Digital voting systems and the option to choose between anonymity and non-anonymity

The two anonymity categories called non-anonymity and anonymity are attached to the possibility of identifying students or the possibility of letting the students respond anonymously, respectively. These categories can be coupled with both instructors and students. Furthermore, a classification can be made to account for the instructors' level of skill with using digital voting systems as a communication/ learning resource and also as a control mechanism, a testing apparatus and a mechanism that awards course points. In other words, this differentiation into different categories can be seen as a foundational premise for observing the addressee's (instructor) approach to digital voting systems' answers from students – and the utterer's (student) approach to responding using digital voting systems.

Instructors who chose non-anonymity did so to identify the students individually, thereby giving them the chance to follow their academic development. Assessment of the student's progress would thus be enabled through accessing a new informational level.

The students did not consider non-anonymity to be a problem, but rather regarded it as a resource, which gave the instructor "the possibility of seeing how each individual develops" and they *expected* the instructor to make use of this knowledge in, for example, a counselling role.

They pointed out that it wasn't the instructor they were afraid of being embarrassed in front of, but "if you sit in an auditorium with 200 people, you won't be so likely to put your hand up, if you are not completely sure".

They differentiate therefore between "anonymity with reference to the instructor" and "anonymity with reference to peers".

The latter category doesn't allow for the 1st and 2nd selection of a communication unit to be observed and there is thus a special form of communication where the singular informational voting response (the digital voting system's answer) cannot be included. This does have its advantages, as the students pointed out. Looking at it from a systems theoretical perspective, we might see this as a disadvantage, if the communicative contributions from the students are mediated exclusively through digital voting systems. The group, when viewed as a social system, can be seen to lose communicative possibilities if there is no further expansion of voting possibilities through an invitation to participate in oral arguments and discussions.

The students didn't think that digital voting systems should be used as a form of continuous control or for testing purposes. They felt "that would be super stressful" and "You should also be allowed to answer incorrectly". They saw digital voting systems as a resource that could be used in connection with answering, where answering provided a possibility for making further links to the academic material. They pointed out that they also learnt by giving wrong answers using the digital voting systems and they appreciated the information that was provided after the voting. This enabled them to gauge themselves in comparison to the other students. Digital voting systems also afforded them the opportunity to reflect upon academic questions and argue immediately after a voting session. One student also remarked that they:

> sit forward in their seats, because there is a flow in this class [...] it isn't just a boring lecture, where I am sitting and almost fall off my seat, we don't doze off here...you need to educate instructors in how to use digital voting systems.

They added that they appreciated variation in the presentation and review stages. Blackboard and chalk were still considered a good way of getting them to process the material as one could follow the process on the

blackboard, while the students thought that digital voting systems were mainly useful for classroom lectures.

> It would be difficult to implement digital voting systems in a setting with smaller groups as, chances are, everyone would normally always agree.

In summary, the students felt that digital voting systems were not so useful in situations when students were working in groups and when the instructor was not imparting information to the whole class.

Considering these responses through the lens of systems theory, when communication takes place face-to-face and when this is made possible between a few people only then we can conclude that the complexity of the system is reduced. There is also an increased possibility for expressing oneself in such a system and for becoming a part of the dialogue.

The Danish students who voiced their opinions on digital voting systems' usage experienced situations where the systems were employed as communication and learning support tools for students, and also for instructors. In the two cases under discussion, the systems were not employed to check, control or test. The instructors' approaches to using digital voting systems in assessment and continuous feedback activities as well as support for continual knowledge construction, were viewed as positive by the students. The Danish students' positive critique of the instructors' teaching skills, in particular their critical reflection over the students' digital voting systems digital voting systems responses and the subsequent discussion, does indicate there is a place for the pedagogical development of instructors in the use of digital voting systems

Benefits of digital voting systems for different students

The students differentiated between the "elite" and "the majority" of students in connection with the use of digital voting systems in teaching. The general opinion was that digital voting systems would not improve learning gains among elite students, but that they would benefit the majority of students. One of the students mentioned that:

> The elite are pretty good at managing without any additional help. One could imagine that digital voting systems would be seen by this group as being an impediment- slowing the teaching down […] Digital voting systems slow down the learning and bring others down with them.

Another of the students mentioned that:

> the elite do get an opportunity to explain to others, and in that way they too can get something out of it. It does require though, that they make an effort to participate in discussions.

According to some of the students, this was not always the case.

Conclusion

The study of classroom lectures at two Danish universities that included the use of digital voting systems revealed that both students and instructors viewed the technology as a positive addition to the teaching toolbox. The study was conducted in settings where classroom lectures were the preferred teaching method and where the study of continuous communication among the students with digital voting systems was observed both by the instructors and the students themselves. Digital voting systems were viewed from the perspective of being a communication and a learning resource.

If we view this communication setting through the lens of systems theory, we can see that there are several choices and follow-up actions open to both the students and the instructor. The students can choose to focus their attention on the communication and they can also choose to participate by communicating. The sentient choice of participating through voiced communication applies to both the students and the instructor. This is evident in the instructor's choice of information, the type of digital voting system questions posed, the possibility for voting followed up by dialogue about the results, the optional subsequent exploration of the theme and any revision of answers that might be needed.

Digital voting systems provide students with a tool for assessing their own conceptual understanding. This is viewed as the primary digital voting systems' function both by students and instructors. The focus in this particular study has, however, been to view digital voting systems as a resource for promoting continued knowledge construction – both with regard to the instructor's possibility for constructing knowledge and building upon their teaching practice, and also in respect to the students' academic progression and the inherent possibility for actively participating in class communication.

Incorporating digital voting systems in the teaching setting can prove time consuming, especially as they provide space for elaborated communication upon the subjects discussed. As evidenced by the responses from the students involved in the two cases, this feature can be seen as a positive enhancement to learning settings and as something advantageous by the "majority of students". The flow of the teaching can be disturbed or impeded through overuse of digital voting systems and this of course neither helps the "majority of students" nor the elite students.

The Danish students didn't mind not having the option of anonymity, as long as the instructors' intentions were to use the information in a way that would support the students' academic development. They needed also to be assured that this information would not be used for control purposes or for giving out "credits" for course participation. In actual fact, the students anticipated that the constructed knowledge that was generated through the use of digital voting systems would be put to use afterwards in individual advisory sessions that would be held for each student by the instructor.

There is a difference in the way digital voting systems are used in teaching and education, as is apparent in the

literature. Much literature, for example focuses on the use of digital voting systems as tools for test, control and allocation of credits, which contrasts with the focus on communication found in this study. The observation that digital voting systems have a use outside straightforward assessment is crucial to our understanding of how we might incorporate such a technology into our teaching contexts, for it imparts an understanding of digital voting systems technology as a tool- as something that can be used, and it reminds us that technology does not in itself determine that use, nor the manner in which it is used.

In short, if used without discernment, digital voting systems could become tools of trivialization, but when used with discernment, they provide excellent support for enhancing knowledge construction within non-trivial systems. The individual instructor's pedagogical and didactic competences are determining in this setting-they determine how well digital voting systems are put to use and have a direct impact on the benefits that can be seen with the technology.

This study of digital voting systems has inspired a number of observations relevant to most educational settings at universities. The study, now complete, also raised a number of questions:

- How can all students be given an opportunity to express their reasoning behind their voting? How can we ensure academic feedback to students' voting responses?
- How are the different types of questions in digital voting system to be matched with different academic goals?
- What learning gains/potential can be seen with regard to different groups of learners?
- Is there learning potential in letting the students formulate questions in digital voting systems, and if so, what are the kinds of learning benefits that can be identified?
- Can we envisage digital voting systems implemented in settings where they support the development of concrete skills, knowledge and competences?

The author raises these questions in the hope of encouraging further research and discussion on the use of digital voting systems in higher education settings.

Author Information

Helle Mathiasen is Professor at the Faculty of Science, University of Copenhagen, Department of Science Education, Denmark. Since the mid-'90s her research has revolved around use of digital media and net-based teaching and learning environments in high school and higher education. Mathiasen has been a member of national and international boards concerning pedagogy, teaching, learning and use of IT in the educational system, and has served as a guest professor. She has written several articles and edited books on the field.

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