BUZZ – Acoustical Engineering Methodologies to Measure Student Engagement

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***Abstract**: Assessment of engagement of students relies heavily on self-report by students or time-consuming visual observations. This research project describes an acoustical measurement of engagement and reports findings of an exploratory study on acoustical patterns of engaged students in team, lecture and informal learning settings.*

Introduction and context of the study

With a call for more teamwork and collaborative learning methods in engineering and other disciplines, the teaching community faces challenges on how to rigorously assess students' engagement during learning sessions (lecture, team, laboratory). Existing assessments can be classified into four categories: (1) Assessment by proxy: the end product exceeds the set of criteria and expectations; therefore the input of the students must have been of a similarly high quality; (2) Self-reported data from team members – after the fact – in which team members rank each other and themselves on a variety of different criteria; (3) Ethnographic (immersive settings) and (4) Observational methods, from anecdotal/unsystematic observations to validly constructed observation protocols. It can be argued that the more rigorous, objective, and real-time, the more time and resource intensive the assessment.

This research project (BUZZ) seeks to develop a model of measurement of learning and engagement in physical social spaces. The developed model will be acoustics-based. In its ultimate form, this research will be able to describe and evaluate engagement and learning by analysing the sound and the acoustics of the social space in which it occurs.

The second objective of this paper is to contribute an additional aspect to the landscape or ecology of engineering education: The most widely utilized conceptualization (as evidenced by the increasing number of rigorous research literature) would argue that engineering education is the adaptation and utilization of educational research methodologies in the different disciplines of engineering. The relationship with education, however, can also be seen as bidirectional, in which engineering education is seen as contributions of technical engineering research to the many aspects of the educational systems. This paper makes a case and a contribution for the latter.

Research questions

The research is driven by the following questions: (1) How do the acoustics and the sound of an engaging social interaction of students differ from the acoustics/sound of a less engaging interaction? (2) What are acoustic characteristics of physical spaces with a high affordance of interaction? (3) How feasible, reliable and valid is a model of acoustics measurement of social spaces of learning and engagement?

Specific hypotheses are: It has been observed, but not quantified, that there is a correlation between student-generated 'noise' and their level of engagement in a learning environment. Lack of noise may also correlate to the level of student engagement and has been observed to occur during periods of high one-way engagement. This study proposes to quantify this correlation and validate the acoustical data via an observation-based model. By making audio recordings of lab and lecture activity while concurrently observing and recording student engagement events, the researchers aim to produce a viable acoustics- and observation-based model of student engagement.

Theoretical frameworks

It has been long accepted that attention is required for successful learning of any given information, task, or skills (Andre, & Phye, 1986; Atkinson, & Shiffrin, 1968; Grabe, 1986; Kulhavy, Schwartz, & Peterson, 1986). However, attention is a necessary but not a sufficient variable in the equation of effective learning. Recent views on this particular topic have shifted from attention to student engagement, which is a more inclusive variable, to better address the complexity of learning.

According to Appleton et al. (2006), Fredericks, Blumenfeld, & Paris (2004), Skinner and Belmond (1993) and Klem and Connell (2004), student engagement consists of multiple components, which are behavioral, emotional, and cognitive:

- Behavioral engagement: time on task, intensity of concentration and effort, tendency to stay on task, propensity to initiate action when given opportunities, participation;
- Emotional engagement: enthusiasm, optimism, curiosity, valuing learning, interest versus boredom, happy versus sad or angry;
- Cognitive engagement: self-regulation, goals, and understanding of the reason and the importance of the task to be done.

The relationship between engagement and effectiveness of learning has been discussed and emphasized by numerous researchers (Ahlfeldt, Mehta, & Sellnow, 2005; Appleton, Christenson, & Furlong, 2008; Harris, 2008; Newmann, 1992). This notion has also been supported by empirical studies (Fredericks, Blumenfeld, & Paris, 2004; Furrer, Skinner, Marchand, & Kindermann, 2006; Klem & Connell, 2004), either in terms of students' participation in school activities in general or during classes specifically. For example, Voelkl (1995) examined the relationships between teacher support, student participation, and academic achievement with a sample of 13,121 eighth-grade students attending public schools. She found that students' participation in class played a prominent role in their academic achievement.

Several approaches exist to measure student engagement in classroom: Appleton and Christenson (2004) constructed the Student Engagement Instrument (SEI). The SEI contained 30 items that were designed to measure the level of cognitive engagement and 26 items measuring psychological engagement. Other means to measure student engagement also include checklist, rating scales, and direct observations (see Chapman 2003 for details). However, among the studies in the area of measuring student-class engagement, the most commonly used measures, according to Chapman (2003), are self-report, including student response systems which have been used to provide information in real time about students' class engagement, such as Student Response System (SRS) (Blood & Neel, 2008) or Group-Response Technology (GRT) (Foegen & Hargrave, 1999).

Self-report or teacher-observation/report could provide valuable data for assessing the level and types of student engagement during class activities or lecture. Yet, it could be skewed by the reporter's subjective perception or observer's own interpretation of the behaviours of the students being observed. More objective means are needed for providing a reliable and consistent measurement of student class engagement. Moreover, using teacher observations, rating scales, or self-report for gathering student engagement information may not be realistic in most college classes, especially the large sized lectures that often have more than 100 students. While instruments to capture engagement during human-computer interaction activities exist (Bulger et al., 2008), no tools exist in a face-to-face classroom to provide the instructor with the student engagement data in real time.

Methodology

The research employed a mix-method study, relying on visual observation of engagement and quantitative analysis of events and non-events of engagement. The research team chose two different settings for measurement: (1) A large lecture hall in a psychology classroom (capacity 400) and (2) An engineering project computer laboratory serving teams and individuals.

The research team conducted two types of data collection, visual and auditory. A well-described and rigorously tested observation protocol (Van Amburgh, 2007) was used for visual data collection and was expanded to include a timestamp field. The instrument was utilized to capture times of engagement and classify the type of engagement based on the instrument's categories of active learning. With a synchronized stopwatch, the event times were marked and later used in the analysis phase to retrieve the audio recordings of the event.

An acoustical recording was set up in parallel to visual observations. An Audio-Technica AT8010 microphone was chosen as the receiver for its omnidirectionality, wide frequency response (20 Hz – 20 kHz), and low cost. The microphone was set up in an unobtrusive location with the intent of capturing all activity in the room equally. This microphone was routed onto Audacity on a laptop computer for lossless data storage. Audacity is a free audio recording program which allowed audio files for each recording session to later be cut into events as recorded on the observational data sheets; non-events were chosen during times when no engagement was observed.

The occurrence of an event was determined subjectively. If an observer witnessed a marker of student engagement, the time, length, quality, and degree of the event would be noted. An engagement event was identified as a spike or lull in noise levels, or a change in the quality of communication that the observer determined to be correlated in some way with student or team engagement.

The development application Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) by National Instruments was used to extract data from the audio recordings. A pre-built application (Getting Started with SV Express VIs) was used to analyze the audio files created from the event recordings. The 1/3rd octave sound power graph displays the sound power at each 1/3rd octave band between 20 and 16000 Hz. This portion of the application was modified to export the frequency and sound power data points to a text file. The band power calculator returned the sound power in decibels for any defined frequency range.

The band power calculator was used to obtain the band power in five frequency ranges: 20-512 Hz, 512-2048 Hz, 2048-20000 Hz, 512-1024 Hz, and 1024-2048 Hz. These frequency bands were chosen based on the known frequency characteristics of human speech. Speech intelligibility requires frequencies between 512-2048 Hz, meaning speech sounds created by humans primarily occur in this region. Based on this knowledge, the five frequency ranges provide sound power data below, in, and above the frequency range of human speech.

After the audio files were divided into frequency bands in LabVIEW, the raw frequency data was imported into MATLAB for normalization, averaging, and plotting. Normalization was required to establish a consistent level between recording sessions because the microphone was not calibrated prior to making recordings.

Findings and conclusions

Four recordings were made with concurrent observations and a total of 38 events and 17 non-events were identified and analyzed. One recording was made in a lecture hall and three were made in an engineering project computer laboratory. Preliminary results show a level variance between engagement events, particularly when comparing acoustic characteristics within the range of human speech. This is expected, as student engagement is often accompanied with student-generated noise.

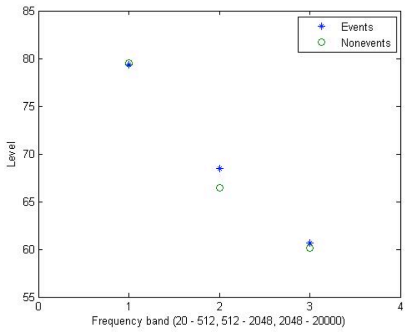

Figure 1: Average event and non-event levels in frequency bands below, within, and above the approximate range of human speech

Figure 1 (all events and non-events averaged) shows that events produced greater levels in the frequency band of human speech than non-events. This is particularly interesting considering that non-events were not exclusively silent, but could contain high levels of human-produced sound such as off-topic conversation, a movie, or a loudly speaking instructor in the classroom.

Figure 2 details all 38 events and 17 non-events, showing the normalized, time-averaged level of each. While events are more likely to range at higher levels particularly around the human speech frequencies, there is a strong compression and pattern building in which events and non-events cannot be distinguished; several non-events show similar high levels at the same frequency bands. These findings would indicate that although events are discernable on average, to detect individual events seems more difficult. A more targeted analysis was needed.

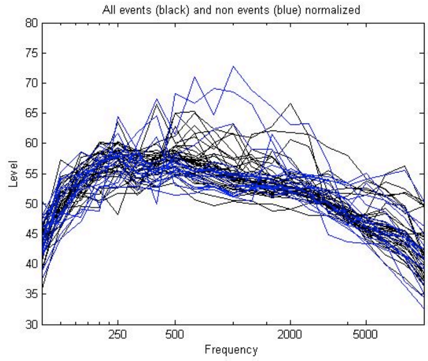

Figure 2: Average event (black) and non-event (blue) levels - normalized from each recording

Focusing on individual events, one is shown in Figure 3, and non-events (Figure 4) as they change through time produces new insights. Some events demonstrated considerable variance in the human speech frequency range as compared with non-events from the same recording. Because some non-events had activity in the speech range, the researchers attempted to quantify the degree of this activity to clearly differentiate the events and non-events.

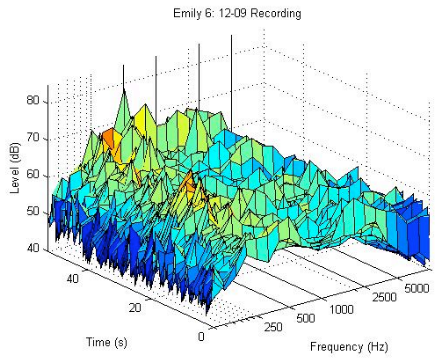

Figure 3: Engagement event from a computer lab recording

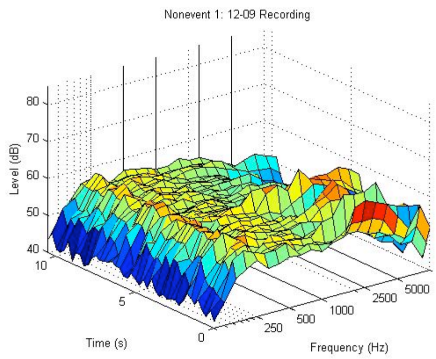

Figure 4: Non-event from a computer lab recording

Further focusing the range of analysis, peak levels of events and non-events within the human speech range 500 – 2500 Hz were compared (for each event and non-event, the peak level within the frequency range was found at each time interval and compared to the average peak level). To quantify the variation within the speech range, the standard deviation of the peak levels from the average level was calculated for each event and non-event from one of the computer laboratory recordings (Table 1). This allows a comparison of the variation in level for each event and non-event. Engagement events were found to have a greater standard deviation of peak levels within the human speech range overall than non-events, suggesting that the quality of activity is different between events and non-events.

Table 1: Standard deviation of peaks of events and non-events within human speech range

Event 1	1.80	Non-event 1	2.38
Event 2	2.66	Non-event 2	2.19
Event 3	3.78	Non-event 3	0.88
Event 4	3.32	Non-event 4	2.30
Event 5	3.42	Non-event 5	2.58
Event 6	4.51	Non-event 6	2.18
Event 7	5.55		

Recommendations and future research plans

We identified several directions for future research: For simplification, the events and non-events from each session were averaged to provide one curve for each type of observation. This allowed for easy comparison between recordings. Some analysis was done with higher resolution; that is, a few events were chosen to be observed individually, and this analysis could be expanded to include more events and non-events. Furthermore, weighting factors may need to be applied when considering the quality or degree of an engagement event, or events will need to be re-examined to determine where the greatest levels of student engagement occurred.

In addition, it might be essential to determine which type of engagement in which type of learning setting is more prone to detection with our acoustical measurement process in real-time. Similarly, more granular research is necessary to be able to confirm in a full experimental setting the reliability of the measurement.

At this point, the research team welcomes feedback and advice on future directions, different approaches and additional frameworks and methodologies.

References

Ahlfeldt, S., Mehta, S., & Sellnow, T. (2005). Measurement and analysis of student engagement in university classes where varying levels of PBL methods of instruction are in use. Higher Education Research & Development, 24(1), 5–20.

Andre, T., & Phye, G. D. (1986). Cognition, learning, and education. In G. D. Phye, & T. Andre, (Eds.), Cognitive classroom learning: Understanding, thinking, and problem solving (pp. 1-18). New York: Academic.

Appleton, J. J., Christenson, S. L., & Furlong, M. J. (2008). Student engagement with school: Critical conceptual and methodological issues of the construct. Psychology in the Schools, 45(5), 369-386.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. Spence, & J. Spence (Eds.), The psychology of learning and motivation (Vol. 2, pp. 301-355). New York: Academic.

Bachorowski, J. –A. (1999). Vocal expression and perception of emotion. Current Directions in Psychological Science, 8(2), 53-57.

Banse, R., & Scherer, K. R. (1996). Acoustic profiles in vocal emotion expression. Journal of Personality and Social Psychology, 70, 614-636.

Blood, E., & Neel, R. (2008). Using student response systems in lecture-based instruction: Does it change student engagement and learning? Journal of Technology and Teacher Education, 16(3), 375-383.

Bulger, M. E., Mayer, R. E., Almeroth, K. C., & Blau, S. D. (2008). Measuring learner engagement in computer-equipped college classrooms. Journal of Educational Multimedia and Hypermedia, 17(2), 129-143.

Foegen, A., & Hargrave, C. P. (1999). Group response technology in lecture-based instruction: Exploring student engagement and instructor perceptions. Journal of Special Education Technology, 14(1), 3-17.

Fredericks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. Review of Educational Research, 74, 59-109.

Furrer, C. J., Skinner, E., Marchand, G., & Kindermann, T. A. (2006, March). Engagement vs. disaffection as central constructs in the dynamics of motivational development. Paper presented at the Annual Meeting of the Society for Research on Adolescence, San Francisco, CA.

Grabe, M. (1986). Attentional processes in education. In G. D. Phye & T. Andre, (Eds.), Cognitive classroom learning: understanding, thinking, and problem solving (pp. 49-82). New York: Academic.

Hammerschmidt, K., & Jürgens, U. (2007). Acoustical correlates of affective prosody. Journal of Voice, 21(5), 531-540.

Harris, L. R. (2008). A phenomenographic investigation of teacher conceptions of student engagement in learning. Australian Educational Researcher, 35(1), 57-79.

Kass, H., & Macdonald, A. L. (1999). The Learning Contribution of Student Self-Directed Building Activity in Science. Science Education, 83(4), 449-471.

Klem, A. M., & Connell, J. P. (2004). Relationships matter: Linking teacher support to student engagement and achievement. Journal of School Health, 74(7), 262– 273.

Kulhavy, R. W., Schwartz, N. H., & Peterson, S. (1986). Working memory: The encoding process. In G. D. Phye & T. Andre, (Eds.), Cognitive classroom learning: understanding, thinking, and problem solving (pp. 115-140). New York: Academic.

McGill University Medicine Neuropragmatics and Emotion Lab. Neurocognitive studies of speech prosody. Retrieved July 22, 2008, http://www.mcgill.ca/pell_lab/projects/investigations

Newmann, F. (1992). Higher-order thinking and prospects for classroom thoughtfulness. In F. Newmann (Ed.), Student engagement and achievement in American secondary schools (pp. 62–91). New York: Teachers College Press.

O'Connor, J., & McDermott, I. (1997). The art of systems thinking: Essential skills for creativity and problem solving. London: Thorsons.

Shigeno, S. (2004). Recognition of vocal expression of emotion and its acoustic attributes. Japanese Journal of Psychology, 74(6), 540-546.

Skinner, E.A., & Belmont, M.J. (1993). Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. Journal of Educational Psychology, 85(4), 571-581.

Van Amburgh, J.A., Devlin, J.W., Kirwin, J.L. & Qualters, D.M. (2007) A tool for measuring active learning in the classroom. *American Journal of Pharmaceutical Education, 71*, 5, 85.

Ververidis, D., & Kotropoulos, C. (2006). Emotional speech recognition: Resources, features, and methods. Speech Communication, 48, 1162-1181.

Voelkl, K. (1995). School warmth, student participation, and achievement. Journal of Experimental Education, 63(2), 127-138.

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