TABLET PC INSTRUCTIONAL STRATEGIES FOR STRUCTURED COMPUTER USE: AN INSTRUCTOR'S EXPERIENCE AND STUDENT PERCEPTIONS

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Abstract

Increasingly, engineering programs are requiring their students to bring personal computers to class in order to engage in technology-centered instructional activities. Research studies have documented both advantages and disadvantages of technology in the classroom. For the most part, positive engagement and learning results are reported when classroom computer use is structured. However, for an instructor seeking to incorporate structured computer use, time requirements for learning the technology and modifying lectures is a major barrier. This paper presents the results of an action research study designed to elicit "best practices" for incorporating structured computer use into a technology-infused classroom. Through observations of expert instructors, and a review of literature, the authors identified six Tablet PC instructional strategies that can be employed to create structured Tablet PC use within a technology-infused classroom. Those strategies are 1) digital ink, 2) distributing instructor-generated content, 3) collecting student-generated content, 4) blacking out the projector, 5) polling questions, and 6) instructor screen broadcast. Student interviews, instructor experiences, and a preliminary student survey were used to understand the benefits and drawbacks of each of these strategies. The study results reduce the time requirement for incorporating structured Tablet PC use in additional classrooms by summarizing the "best practices" from this experience.

Introduction

Faced with an increase of personal computers in the classroom and an increase in disengaged students, instructors are increasingly instituting classroom technology bans to remedy observed negative behavior[1,2,3]. Technology bans are consistent with literature documenting significant off-task behavior[4] and literature revealing a negative correlation between laptop use and student learning[5]. However, as engineering programs increasingly require their students to purchase personal laptops for the purposes of augmenting in-class instruction, banning laptops in the engineering classroom leads to a paradox.

The solution to this paradox for engineering programs lies in embracing laptops rather than banning them. While several studies illustrate the negative effects of classroom technology, there are also several studies asserting the positive effects (e.g., [6,7,8,9]). The main difference between these conflicting studies is that those studies asserting positive effects of laptops have focused on classrooms with structured computer usage. Kay and Lauricella define structured computer use as the instructor guiding and directing usage[9]. This is in opposition to unstructured use where students use the machine as they please. Consistently, structured use has been shown to increase student attitudes and successful behaviors that support learning. Since positive attitudes and successful behaviors emerge with structured use in classrooms, it is prudent to include structured laptop use in engineering programs with a personal laptop requirement.

While structured computer use has the potential to increase student engagement in large lectures via engaging media, interactive polling, or computer-based think-pair-share activities, the reality is that many instructors lack the resources to incorporate structured computer use into their lectures. Particularly, instructors have reported that one of the top barriers for incorporating computers into classroom activities is time[10,11]: time to learn the technology and time to modify lectures[10]. One suggested solution towards reducing the time requirement for incorporating

computers is to create and distribute lesson plans involving structured computer use[12], which provide roadmaps for future faculty adopting technology. Similarly, reporting the experiences of individual instructors incorporating technology into their classrooms (e.g., [13,14]) can result in a set of "best practices" that can be used by future instructors.

In this paper, we take the latter approach and report on the experience of an instructor newly assigned to teach in a computer-infused classroom (referred to as "new instructor" in this paper). Sharing the experience of incorporating structured Tablet PC (TPC) use into a lecture of 93 first-year engineering students is a way to potentially reduce the time requirement for other instructors seeking to incorporate structured computer use into their own classrooms. Reducing the time requirement is important since it is one way to increase technology adoption levels[10].

Methods

Setting

The study was conducted at a large research university located in the Southeast United States. Each fall semester, the College of Engineering at the study site enrolls approximately 1400 new general engineering students. The College of Engineering has an established TPC requirement, and compliance with the requirement is near 95%. The College of Engineering makes available course management software, primarily to distribute course content (e.g., slides) to students. In addition, the software can be used to implement various instruction interventions including polls, electronic ink, and screen broadcast. Instructor training is available for the software. New instructors are encouraged to observe more experienced instructors classrooms for TPC incorporation strategies.

The first-year engineering program consists of a two-semester course sequence. Each semester-long course is composed of one 50-minute large lecture (ranging from 75-300 students) and one two-hour, hands-on laboratory (approximately 30 students) each week. This research study investigates a new instructor assigned to teach one

of the large lectures (93 students) for the second sequence course in Fall 2011. Student familiarity with TPCs is usually higher in the second sequence engineering courses because TPCs are used in the first sequence course.

Action Research

The objective of this study is to explore strategies of incorporating structured TPC use into classroom instruction for an instructor new to technology-infused classrooms. In this initial study, strategies were evaluated based on both student- and instructor-perceived effects on attitudes and learning. This study takes an action research approach. Action research in an educational setting is a systematic investigation performed by a practitioner with the intent that the research results will directly inform and improve teaching and learning[15] and is often seen as a tool for professional development[16]. Action research is an appropriate method because this study involves the personal investigation and experiences of an instructor incorporating structured TPC use in the classroom to improve student interaction. Furthermore, this study topic is consistent with McMillan's criteria for action research[15]: the area of study 1) involves teaching, 2) is part of the researchers' personal practice, 3) is something the researchers have control over, 4) is something that can be changed, and 5) is something the researchers are motivated to learn about.

While the research study followed the entire cyclical process of action research[17] this paper focuses on two phases: 1) Action Planning and 2) Action Taking. During the Action Planning Phase, a literature review was conducted to identify potential ways in which the new instructor faced with teaching in a technology-infused classroom could incorporate required student TPCs into lecture activities. In addition, qualitative methods focused on experiencing and inquiring[15] were used:

- TPC incorporation was experienced through observations in two first sequence classrooms that were taught by instructors who had previous practical experience teaching with TPCs. (These instructors are

referred to as "expert instructor" in this paper).

- TPC incorporation was inquired about through five one-on-one interviews with students in those same expert instructors' classrooms.

The new instructor took part in the observations and the interviews.

During the Action Taking Phase, the new instructor incorporated structured TPC strategies (identified in the previous phase) into their own second sequence classroom. This experience is discussed. An initial evaluation of incorporation is also discussed both through the new instructor's personal observations and a preliminary student survey. The survey is designed to measure non-cognitive behaviors with a survey of student attitudes towards TPC incorporation in the new instructor's classroom.

Data Collection

Data was collected in both first sequence and second sequence courses in the 2011 fall semester. During the Action Planning Phase, observations and interviews were conducted within the first sequence course. The primary motivation for this choice was to ensure that expert instructors could be selected for observation. Since the fall semester is "on-sequence" for the first sequence course, enrollment is high, and more instructors are assigned to the course. During the Action Taking Phase, data was collected from the new instructor's course, which was a second sequence course.

During the Action Planning Phase, multiple data collection methods were used. Two observations of two instructors experienced with structured TPC use were conducted. The first observation was conducted to identify TPC interaction strategies. The observation period was a full 50-minute lecture period and observers (including the new instructor) sat in the back of the classroom where they could observe most students' computer screens and the lecturing instructor. Following the observation, students were recruited for one-on-one open-ended interviews. During interviews students were encouraged to describe their overall experience with TPC in the classroom and to specifically describe their experience with identified TPC interaction strategies. The second observation was conducted following the interviews to improve understanding of situations the students described in interviews that were not observed in the first observation session. The second observation session was a partial lecture period.

During the Action Taking Phase, the new instructor incorporated TPC interaction strategies for structured TPC use throughout the course. The initial evaluation of incorporation is discussed both through instructor narrative and a preliminary student survey. The survey was an initial evaluation of student attitudes for the six strategies. Questions addressing students' perceptions and attitudes were measured on a 5-point Likert-scale with 1 indicating Strongly Disagree and 5 indicating Strongly Agree. The survey also included several open-ended questions asking students to explain their rationale behind various attitudes. Quotes provided are from those open-ended survey questions. Of the 17 respondents, all reported they expected an A or B final course grade, three did not adhere to the TPC requirement and instead purchased laptops, two were female, and the average age was 20 years old.

Analysis

During the Action Planning Phase, literature, observation, and interview data were coded for themes using open-coding methods. During the initial coding, codes related to specific TPC instructional strategies were identified. During the second phase of coding, data were analyzed for benefits or drawbacks related to the identified instructional strategies. During the Action Taking Phase, due to the low response rate (17 of 93), responses were used as indicators of attitudes rather than for test of statistical significance.

Results

This section is organized according to the six main instructional strategies that were identified during Action Planning: digital ink, distributing instructor-generated content, collecting student-

generated content, blacking out the projector, polling questions, and instructor screen broadcast. This section defines each strategy, and presents the results from the action planning and action taking phases.

Digital ink

Digital ink refers to the ability to directly write on computer documents with a stylus, or virtual pen. Digital ink is what separates tablets from traditional laptops[18]. Also, Johri and Lohani argue that allowing students to create representations is valuable from a cognitive perspective[19]. Therefore, it is wise to include digital ink in instructional activities when a university has a TPC requirement versus a laptop requirement. Digital ink use is widely reported in the literature. The most common method of incorporating digital ink into the classroom is via instructor and student annotation of instructor-created content (e.g., lecture slides)[18,20]. In the typical case, an instructor annotates slides and those annotations are passed on to the student. Then, the student can add further, personal annotations. Due to its availability in a limited number of software packages, one less reported use of digital ink is for the instructor to annotate their own projected slides, with these private annotations appearing only on the projected slides and not on the students' personal copies. This use requires students to add their own annotations since instructor notes are not directly passed on. This use would be most similar to writing on whiteboard and having students copy notes.

Action Planning

During classroom observations for this study, most students appeared to be viewing instructor annotations. Approximately one-third of students were observed adding their own annotations to slides. Since less than two full lectures were observed, it is possible that more student annotation or note taking took place. During interviews, positive attitudes regarding digital ink emerged. When asked which TPC feature was the most useful in class, one participant exclaimed, "*The writing!*" without hesitation. That participant elaborated on his enthusiasm:

"*[With a TPC], I can take up the lecture notes and actually just write on that. Instead of having to deal with printing it out and having all this paper to deal with and binders... cause honestly uh this is uh so much easier to just carry a laptop and have everything on there than dealing with five or six binders.*"

Having instructor-generated content, instructor annotations, and student annotations all in one place for all of a student's classes is a more efficient proposition.

Action Taking

Digital ink was incorporated into the classroom in fairly traditional ways: the instructor and students annotated lecture content. To gauge attitudes, the instructor purposefully alternated between annotating lecture content on students' computers (through the course management software), using private ink to annotate only the instructor's projected slides, and writing notes on the chalkboard in the front of the room. Students were free to annotate or take notes however they chose.

Although note taking is often cited as a major benefit of TPCs, at the end of the semester, a majority of the survey respondents indicated a low frequency of note taking with their TPC (see Table 1). This is consistent with the findings of Moore and coauthors,[18] who reported lower than expected student note taking. A possible explanation for this could be that students have not developed proper note taking skills (six students also indicated they did not take notes on paper). Since eight students indicated they took notes with pen and paper, another explanation could be that students are not familiar or comfortable with TPC features that support note taking. Also, as discussed in [18], teaching style or lecture topics may factor into student note taking. This finding regarding student note taking is inconsistent with student interview responses during the Action Planning Phase. Students who participated in interviews were very positive about the ability to take notes on their TPCs. Since those students were new to TPCs, the newness of the technology, which has faded by the end of their second semester, could be a reason for this difference.

On a positive note, students indicated that they were more likely to pay attention in lecture when the instructor was actively annotating slides (see Table 2). However, instructors should annotate slides carefully as one respondent pointed out: "Sometimes an instructor writing on the slide ruins the value of the slide for me as the notes are only distracting." Students had a slight preference for the instructor annotating directly on student slides over the instructor writing on the chalkboard. Students were neutral regarding the instructor annotating instructor slides (and not student slides). One respondent explained the benefit of instructors using digital ink: "Having the slides and [the instructor's] notes were helpful in studying for tests." What is not clear is whether the notes marked with an instructor's digital ink are any more valuable from a learning perspective than providing students with unmarked slides and having students write their own notes.

Table 1. Student survey responses regarding note taking.

Questions (15 Respondents)	N	R	S	QO	VO
I take notes in DyKnow by writing with the stylus.	4	9	1	1	0
I take notes on my computer by writing with the stylus in a program other than DyKnow (e.g., One Note).	7	2	2	1	3
I take notes in DyKnow by typing.	2	4	6	1	2
I take notes on my computer by typing in a program other than DyKnow (e.g., Microsoft Word).	4	3	6	1	1
I take notes with pen and paper.	6	0	1	4	4

N = Never, R = Rarely, S = Sometimes, QO = Quite Often, VO = Very Often

Table 2. Student survey responses regarding instructor annotations.

Questions (15-16 respondents)	SD	D	N	A	SA
I am more likely to pay attention in lecture when the instructor is writing notes on the slides.	1	1	2	**5**	3
I prefer when [the instructor] uses electronic ink to draw directly on my personal slides.	2	1	**5**	3	4
I prefer when [the instructor] uses electronic ink to draw on the projected slides but not my personal slides.	1	3	**9**	1	2
I prefer it when [the instructor] draws on the chalkboard rather than drawing on the DyKnow slides.	4	4	**5**	1	1

SD = Strongly Disagree, D = Disagree, N= Neither Agree nor Disagree, A = Agree, SA = Strongly Agree

Distributing instructor-generated content

Instructors can create lecture content (e.g., lecture slides) and distribute the electronic files through email, on course websites, or in real-time, course management software (e.g., DyKnow, Classroom Presenter). The primary benefit of distributing content is to allow students to take additional notes rather than recreate the content. The primary benefit of using real-time, course management software is that the "push" framework keeps all students on pace.

Action Planning

During observations, students were seen viewing course content pushed to their computers and, when questioned about their perceptions of this strategy during interviews, participants focused on the value of receiving instructor-generated content on their TPCs. One student stated,

"I like it better when I do get something instead of having to deal with writing everything down. That way I can actually listen more."

The student contrasted this positive situation with one in which an instructor writes notes and the student must copy the notes and listen simultaneously. Another participant affirmed the positive combination of distributed instructor content and digital ink:

"*I have [the lecture notes] there and I can do what I want with [them]. Like, I don't have to just leave it. I can take notes and I can add to it.*"

Finally, student participants referenced the ability to see the slides clearly regardless of their location within the lecture hall. This result is consistent with findings in other studies[10]. During interviews, students were consistently positive about receiving and being able to alter instructor-generated content.

Action Taking

The instructor distributed instructor-generated lecture content exclusively through the University's course management software with slides pushed to students as the lecture progressed. All respondents agreed or strongly agreed that having a personal copy of lecture slides helped their class performance (see Table 3).

Table 3. Student survey responses regarding instructor-generated content.

Question (15 respondents)	SD	D	N	A	SA
Having a personal copy of lecture slides helps my class performance.	0	0	0	7	**8**
I prefer to receive slides through DyKnow (versus downloading slides prior to class).	4	1	**5**	3	2
I prefer to receive slides through DyKnow (versus downloading slides after class has ended).	4	2	**5**	2	2

SD = Strongly Disagree, D = Disagree, N= Neither Agree nor Disagree, A = Agree, SA = Strongly Agree

Some students appeared to take issue with the course management software and indicated they would like alternate methods of obtaining instructor-generated content. However, accommodating this request is at odds with structured TPC use to engage students. Instead, additional software training or familiarization may be of benefit to these students. For instance, one student praised the software use, "*It's easier to keep and find [lecture content], stay awake, and follow along.*" Conveying these possibilities to students frustrated by the software may decrease this complaint.

Consistent with the Action Planning Phase, students were positive about having slides on their personal screens, and stated that it "*didn't matter if one was sitting close or far since the notes are right in front of you.*" This result is consistent with other studies that found Tablets solved blocked whiteboards even in small classrooms[20].

Collecting student-generated content

The collection of student-generated content in the structured TPC classroom requires students to create content and electronically transmit that content to the instructor. Creation could occur in a variety of software packages (e.g., Microsoft Word, Adobe Photoshop) and transmission could occur through e-mail or a website. However, course management software takes this idea a step further and allows instructors to retrieve content from students or to accept content submitted by students. Using course management software and a TPC, students can type or write on a blank digital page and then the instructor can retrieve that page from every student. Alternatively, the instructor can ask students to submit the page. Either option results in the student-generated content appearing on the instructor's computer. Instructors can share this content with the course via the projector or the instructor can grade and return this content[18,21]. This type of instructional strategy is supported by active-learning literature.

Action Planning

During expert instructor observations, student-generated content was retrieved only once. The instructor retrieved only a single page of student-generated content; however, that retrieval had a

noticeable impact on engagement. Observers noted that many students who were off-task (e.g., playing online game, accessing email) quickly flipped back to the course management software and followed instructions when they heard that student-generated content would be retrieved. The instructor then displayed the retrieved content on the projector to initiate a discussion with students. Observers noted that student participation when creating content was less than 100% since many of the retrieved pages shown on the projector were blank. During interviews, participants commented that the benefit of content retrieval was that they see other students' ideas, which can help them think of alternate solutions.

Action Taking

Student-generated content was incorporated in several ways. Students were tasked with creating a single slide on the day's lecture topic, students were asked to draw circuit schematics, and students were given multiple-step problems to solve. Throughout the semester, students would perform these tasks both individually and in collaboration with neighboring students. Additionally, techniques such as "muddiest-point" and "think-pair-share" were used to prompt students to generate content for collection. Students were further encouraged to engage in content generation activities because these activities counted towards a percentage of their grade.

Participants agreed they were more likely to pay attention in lecture when the student-generated content was being collected (see Table 4). They indicated no difference in preference for the instructor retrieval of content or for student submission. However, the instructor noted that when retrieving content, many of the retrievals were blank. This is due to the course management software retrieving a content page from every student logged into the software, regardless of whether the student had generated any content. On the other hand, when requiring student submission of content, though not all students submitted, 100% of the submitted slides had relevant information on them. Removing the blank retrieved content pages and comparing the "response rate" to the submitted slides, showed

that students always submitted at a higher rate and submitted material had a higher level of detail. It appears that requiring students to submit slides encourages better engagement.

Table 4. Student survey responses regarding student-generated content.

Question (15 respondents)	SD	D	N	A	SA
I am more likely to pay attention in lecture when slides are being collected.	0	2	1	**6**	3
I am more likely to pay attention in lecture when I am asked to submit a slide.	0	2	1	**5**	4

SD = Strongly Disagree, D = Disagree, N= Neither Agree nor Disagree, A = Agree, SA = Strongly Agree

Blacking out the projector

This instructional strategy was not identified in literature but was observed in expert instructors' classrooms. Essentially, those instructors did not use projection in the front of the classroom, and instead relied on the course management software to provide slides and course content to students' individual TPCs. During informal discussions with these instructors, they indicated that by removing the projected slides, they are essentially removing a second monitor, and encouraging students to focus on the slides on students TPCs rather than off-task applications. Since the course management software pushes content only when the instructor progresses to the next slide, students could stay on pace with their instructor even though they could not see the instructor's screen. Instructors usually taught the entire period with the projector off, except when they showed a quick video or shared content they did not want to pass to students' personal computers.

Action Planning

During expert instructor observations it was unclear if more students were engaged in course content when the projector was off. During the

observation of large lectures, it was not possible for the few observers to constantly monitor student engagement. Individual student as well as overall student engagement appeared to both increase and decrease; no observable pattern could be connected to projector status. Furthermore, since the projected content (e.g., movies) was so different from the non-projected content (e.g., lecture slides), it would be improper to assume any engagement pattern was related exclusively to projector status and was not affected by content type.

Interestingly, when students were asked about this strategy in interviews, they were either positive or neutral (i.e., not negative). However, student reasoning did not match instructor reasoning. Two student participants stated in interviews that blacking out the projector encourages them to focus on their personal computer screen, which prevents them from being distracted by what other nearby students are doing on their computers. One participant described knowing neighbors were playing a game because he could hear them "clicking all the time" but stated:

"It doesn't bother me. I can easily just tune that out especially with everything in front of me rather than being up on that wall. Like that's just a big thing. Having everything in front of me. I have something to focus on a little bit closer and it just keeps me from wandering and getting distracted."

This is significant because Fried argues that student computer behavior can be distracting to other neighboring students who can see or hear the student's activity[5]. Participants did not have an opinion on whether the blacked out projector strategy encouraged more on-task behavior with regards to personal multitasking.

Action Taking

The instructor alternated teaching lectures with the projector on and with the projector off. In all cases, course management software was used to push lecture content to students' personal TPC screens. Several times during the semester, the instructor would have to turn the projector on during a lecture when the projector was supposed to be off because students were not receiving content. This problem was traced to lectures that had multiple images in the day's lecture slides. Pushing this large amount of content to each student would quickly overwhelm the servers, and many students would receive only blank images. Another issue that arose when the projector was blacked out was the delay in students receiving annotations. Though this delay was usually very short, if the instructor made several annotations quickly, the delay would result in students receiving the annotation after the discussion had moved on to another topic. An example: in one lecture the instructor was explaining filters and circled one while stating, "This is a high-pass filter." and circled another stating, "This is a low-pass filter." The server delay resulted in both annotations appearing at the same time on students' screens. Since content was not projected, students were unaware which filter was which.

Survey respondents were neutral regarding any perceive benefits of blacking out the projector. Also, participants did not indicate any effect the blacked out projector had on distraction from neighboring students. In light of the technical issues and the indications from students, we suggest this instructional strategy be more fully examined to determine if the advantages detailed in this section outweigh the disadvantages.

Polling questions

Similarly to clickers, personal computers can be used to ask students a question with each student providing an individual response. This strategy does not require students to identify themselves to other students, and can potentially elicit shy students to participate[18]. Polling questions involve a pop-up window appearing on students' computers. The window contains a question and a set of multiple-choice answers students may choose from. Polling questions can be used to gauge student opinion or quiz students on conceptual understanding[18,19,20].

Action Planning

During expert instructor observations, polling questions directly engaged students. Students,

who were performing off-task actions, would quickly flip back to the course management software and answer an instructor poll. Observers also noted that a higher percentage of off-task students participated in the polls versus the percentage that participated in content retrieval. Participation was likely higher because response to a poll required much less time than response to a request for student-generated content. However, observation notes indicated that after a student responded to a polling question, previously off-task students appeared to return to their off-task behavior. Polling questions did not appear to have long-term engagement effects.

Action Taking

Polling questions were incorporated into the classroom in three ways. First, students were given polling questions in the early stages of a unit's introduction, to find initial misconceptions. Second, polls were used throughout the middle stages of a unit's discussion to verify conceptual understanding. Third, questions were used to provide practice test questions when wrapping up a unit's discussion. After a question was posed, the instructor would wait until the response rate was above 85%, and then show and discuss the results as a class. Discussions of polling question results were always more energetic than if the instructor posed a question aloud to the lecture hall and had students verbally respond. Participants agreed they were more likely to pay attention in lecture when the instructor used polling questions (Table 5).

Table 5. Student survey responses regarding polling questions.

Question (15 respondents)	SD	D	N	A	SA
I am more likely to pay attention in lecture when the instructor uses polling questions.	1	2	0	**5**	4

SD = Strongly Disagree, D = Disagree, N= Neither Agree nor Disagree, A = Agree, SA = Strongly Agree

Instructor screen broadcast

Finally, some course management software allows instructors to broadcast their screen to students' computers, which essentially commandeers the students' computers and only allows students to view a replica of the instructor's computer actions[22].

Action Planning

This strategy was not observed in the classrooms in this study, but was discovered during a review of literature. It is included in this list for completeness.

Action Taking

The instructor incorporated screen broadcast to demonstrate various software packages. Due to the large lecture hall, often students could not see commands typed into software command lines or see small buttons in software user interfaces when these details were projected in the front of the room. By broadcasting the instructor's screen, students could view the demonstrations on their personal TPC screens.

Students were either strongly opposed to or strongly supported the use of screen broadcast. On one of the demonstration days, when the instructor had commandeered students' screens, students were observed frantically clicking their mice, banging on their keyboards, and trying anything they could think of to stop the broadcast. These students ignored the demonstration. Comments in the survey indicate that students who were opposed to the broadcast thought the broadcast was an invasion of privacy and that it was frustrating to "hand over control of my computer." Other students supported the broadcast, since they were able to clearly see the demonstrated content and follow along.

Conclusions

This paper presents the results of an action research study designed to elicit "best practices" for incorporating structured computer use into a TPC-infused classroom. Through observations of expert instructors, and a review of literature, we

identified six TPC instructional strategies that can be employed to create structured TPC use within a technology-infused classroom. Those strategies are 1) digital ink, 2) distributing instructor-generated content, 3) collecting student-generated content, 4) blacking out the projector, 5) polling questions, and 6) instructor screen broadcast. Student interviews, instructor experiences, and a preliminary student survey were used to understand the benefits and drawbacks of each of these strategies. The study results reduce the time requirement for incorporating structured TPC use in additional classrooms by summarizing the "best practices" from this experience. Namely,

- In general, students like receiving instructor-generated content and instructor annotations. Students value instructor annotations, but instructors must be careful to annotate neatly and realize their annotations may overwrite students' own annotations. Student note taking should be supported by ensuring students are aware of the TPC features that support note taking and organization.
- Collecting student-generated content and using polling questions has a positive impact on engagement. However, to encourage more engagement, instructors should request students submit student-generated content rather than the instructor retrieve content.
- Negative classroom features, such as blocked whiteboards, can be overcome by distributing content directly to students' computer screens.
- When blacking out the projector, instructors should ensure students are receiving content in a timely manner.
- Students are polarized with regards to commandeering their computer screens for instructor screen broadcast.

It is the authors' hope that, from these preliminary results, instructors will be better informed in choosing which student-instructor interaction methods to use in a technology-infused classroom. This is relevant, as effectively using new technology in a course requires additional instructor time commitments for technology familiarization and course planning. Sharing experiences and "best practices" is a way to reduce the time requirement with regards to

planning, and to possibly increase technology adoption levels for instructors.

Limitations

The main limitation of this work is that this action research study focuses on one instructor's experiences. While action research is an important research method for studying computer usage in classrooms and can provide many benefits to students in a studied classroom, the transferability of the results to other classrooms is not guaranteed. However, while we acknowledge no two classrooms, instructors, courses, or schools are identical, one practitioner's insights can inform other similar situations.

The second limitation of this work relates to the low response rate for the preliminary survey. Although there could be a plethora of reasons for a low response rate, in this study the low rate is likely due to poor survey administration timing (i.e., the end of the semester) and the high number of surveys students were concurrently completing (e.g., course evaluations, lab instructor evaluations). With so few responses, the results could not be analyzed with statistical tests and the results may not represent the majority. By reporting the results as indicators and determining that the respondents did not belong to a single group (e.g., all A students), this limitation was somewhat mitigated. However, it would be wise to administer the survey again in a future semester.

Future Work

The authors look next to examining how the instructional strategies presented within this paper might affect learning. The research presented in this paper identified multiple TPC instructional strategies that can be used to encourage student engagement in a large lecture. Similar to this study, most other studies that test these strategies rely on anecdotal evidence or short surveys of student and instructor perceptions. All these studies fall short of answering the question, "Do these activities encourage engagement and attention?" This is an important question because many learning theories stress the importance of attention for learning. Future studies should

measure how TPC instructional strategies affect student engagement and attention, thus investigating the strategies' impacts on learning.

Acknowledgements

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